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THE ABSORPTION SPECTRUM OF THE NOVAE

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One of the most remarkable features of the spectrum of novae or temporary stars is the presence at a certain stage in their development of absorption lines displaced greatly toward the violet end of the spectrum. In the case of the elements hydrogen and helium they appear as strong lines forming sharp boundaries to the broad emission bands which are the principal characteristic of the spectrum of such stars. Occasionally they are double and are subject to great variations in character and intensity. In addition to the lines of hydrogen and helium a large number of absorption lines has been observed in the spectra of the three brightest novae of recent years, Nova Persei of 1901, Nova Geminorum of 1912, and Nova Aquilae of 1918. The identification of many of these lines and some features of their displacements form the object of this communication.

Nova Aquilae was first observed at Mount Wilson on June 8. At this time the spectrum was essentially continuous, with a few broad and hazy absorption bands superposed upon it. Most of these were due to hydrogen and helium and were displaced over 20 angstroms toward the violet. Two nights later the entire spectrum had changed: a large number of comparatively narrow absorption lines had appeared and the hydrogen and helium lines had become double. This spectrum had so many points of similarity to that of certain stars that a comparison was instituted with a photograph of α Cygni, a star of early type with exceptionally strong enhanced lines. It then appeared that a considerable number of lines could be identified as common to both spectra provided a displacement of about -23 angstroms at λ 4500 were assumed in the case of Nova Aquilae. A large proportion of these lines are enhanced but some of the stronger arc lines are also represented. In the region of spectrum between λ 3900 and Hβ ninety lines have been identified with considerable certainty, and the origin of many others may be assigned with only slightly less probability.

A similar comparison with the lines measured in the spectrum of Nova Geminorum of 1912[1] shows clearly the presence of many of these lines in the latter star as well. The displacement, however, is only about one-half as great as in the case of Nova Aquilae. To illustrate the character of the lines identified and the displacements involved the results for a portion of the spectrum between λ 4500 and λ 4600 are given in table 1.

The lines in the spectrum of Nova Geminorum are much more hazy and ill-defined than those in Nova Aquilae and the agreement is much less satisfactory. This is due in part to the fact that the earliest photographs of the spectrum of Nova Geminorum were obtained at a longer interval after the discovery of the star than in the case of Nova Aquilae, and that during this interval the absorption lines had begun to grow faint and disappear. About forty lines common to the spectra of these two stars have been identified in the region between Hδ and Hβ.

TABLE 1

WAVE-LENGTH			DISPLACEMENT		ELEMENT	
Sun	Nova Aquilae (June 12)	Nova Geminorum	Nova Aquilae A	Nova Geminorum A		
4501.4	4478.2	4489.3	−23.2	−12.1	Enhanced	Ti
4508.5	4485.3	4495.5	23.2	13.0	Enhanced	Fe
4515.5	4492.0	4505.2	23.5	10.3	Enhanced	Fe
4520.4	4497.1	4508.1	23.3	12.3	Enhanced	Fe
4522.8	4499.2	4511.9	23.6	10.9	Enhanced	Fe
4528.8	4505.3	4518.4	23.3	10.4	Arc line	Fe
4534.1	4510.5	4522.8	23.6	11.3	Enhanced	Ti
4549.8	4526.1	4537.6	23.7	12.2	Enhanced	Fe, Ti
4556.1	4531.7	4543.8	24.4	12.3	Enhanced	Fe
4558.8	4535.0	4547.0	23.8	11.8	Enhanced	Cr
4563.9	4540.1	4551.6	−23.8	−12.3	Enhanced	Ti

It is known from the investigations of Campbell and Wright on the spectrum of Nova Persei of 1901[2] that the displacements of the absorption lines of hydrogen were directly proportional to wave-length in this star, and the same result was found for Nova Geminorum by other observers. The identification of the metallic lines in the case of Nova Aquilae and Nova Geminorum makes a study of their displacements of especial interest in this regard. For this purpose the average displacement and the average wave-length have been formed for groups of lines distributed throughout the spectrum. In the less refrangible region longer intervals have been included because of the smaller number of lines available and the larger range of error in wave-length. The results are given in table 2.

The values for Nova Persei are by Campbell and Wright[2] and those for Nova Aurigae of 1892 are by Campbell and Vogel.[3]

These results may be represented by the following equations in which $\Delta\lambda$ is the displacement. In the case of Nova Aurigae the results are too fragmentary to allow of an accurate determination of the coefficient of λ.

		Displacement at λ 4500
Nova Aquilae:	$\Delta\lambda = 0.00513\,\lambda$	−23.1
Nova Persei:	$\Delta\lambda = 0.00510\,\lambda$	−22.9
Nova Geminorum:	$\Delta\lambda = 0.00257\,\lambda$	−11.5
Nova Aurigae:	$\Delta\lambda = 0.0025\,\lambda$	−11.4

TABLE 2

MEAN λ	MEAN $\Delta\lambda$	NUMBER OF LINES	O−C	MEAN λ	MEAN $\Delta\lambda$	NUMBER OF LINES	O−C
Nova Aquilae				*Nova Geminorum*			
4020	20.8	5	+0.2	4220	10.6	7	−0.2
4155	21.5	4	+0.2	4350	10.9	7	−0.3
4260	22.0	7	+0.1	4445	11.2	5	−0.2
4345	22.5	11	+0.2	4540	11.8	13	+0.2
4450	22.9	7	+0.1	4935	12.8	3	+0.1
4540	23.6	13	+0.3	5896	15.3	1	+0.2
4630	24.0	2	+0.2	6563	17.9	1	+1.1
4820	24.6	4	−0.1	*Nova Persei (H lines)*			
4990	25.5	3	−0.1				
5230	27.2	8	+0.4	3890	19.3	1	−0.5
5350	27.6	8	+0.2	3970	20.0	1	−0.2
5510	28.1	5	−0.2	4102	20.5	1	−0.4
5670	27.8	4	−1.3	4341	22.2	1	+0.1
5890	29.4	5	−0.8	4862	25.7	1	+0.9
6390	32.7	10	−0.1	*Nova Aurigae (H lines)*			
				4102	10.3	1	0.0
				4341	11.4	1	+0.5
				4862	11.9	1	−0.4

The differences, observed minus computed, are given under O−C in table 2. The agreement is close except in the less refrangible part of the spectrum where the determinations of wave-length are least accurate.

We find, accordingly, the surprising result that the displacements of the lines in all of these stars are directly proportional to wave-length and divide themselves into two pairs of equal amount. Of these the first pair of stars has exactly twice the displacement of the second, and it is perhaps a significant fact that Nova Aquilae and Nova Persei were much brighter stars apparently, and probably intrinsically as well, than Nova Geminorum and Nova Aurigae.

A very peculiar phenomenon in the case of Nova Aquilae is the progressive increase in the values of the displacements of the absorption lines at successive dates. Thus in the region between λ 4250 and λ 4600 we find for the dates June 10 to June 15:

June 10	June 11	June 12	June 13	June 15
−21.7(30)	−22.4(30)	−23.0(26)	−23.7(19)	−24.6(11)

During this period the average daily increase in displacement is slightly over 0.5 angstrom. The decrease in the number of lines (given in parenthesis) shows the gradual disappearance of the absorption spectrum within this time.

Reference has already been made to the double character of the hydrogen and helium lines during the interval when the absorption spectrum of Nova Aquilae was prominent. A similar characteristic was found in the case of Nova Geminorum. The less refrangible of these components shows displacements which are in close agreement with those of the absorption lines due to iron and other elements which have been identified. An investigation of the more refrangible component shows that its displacements may also be represented as a direct function of the wave-length. We find for the two stars the relations:

Nova Aquilae: $\Delta\lambda = 0.0075\,\lambda$: Nova Geminorum: $\Delta\lambda = 0.0048\lambda$

The differences as computed from these equations are as follows:

	NOVA AQUILAE (JUNE 12)			NOVA GEMINORUM		
	Observed	Computed	O − C	Observed	Computed	O − C
H.....	30.7	30.8	−0.1	19.4	19.7	−0.3
H.....	31.7	32.6	−0.9	20.6	20.8	−0.2
Hβ.....	37.6	36.5	+1.1	23.7	23.3	+0.4
Hα.....	49.0	49.2	−0.2			

At λ 4500 we find the displacements

Nova Aquilae; −33.8 Nova Geminorum; −21.6

In the case of Nova Geminorum, therefore, the displacement of this component of the hydrogen lines is almost exactly twice that of the less refrangible component and the numerous metallic lines, while in Nova Aquilae it is one and one-half times as great. In other words 11, 22 and 33 angstroms, in the harmonic ratio 1, 2 and 3, represent very closely all the displacements found among the absorption lines in the spectra of these four stars with the exception of the four narrow nearly undisplaced lines of calcium and sodium from which the radial velocities of the stars may be derived. These lines, like the broad emission bands of hydrogen and helium, may perhaps be considered as belonging to the stars themselves, while the greatly displaced absorption lines originate in an outer envelope possibly detached from the body of the stars.

It is certain that no adequate explanation has been offered as yet to account for these immense displacements. Were the hydrogen and helium lines alone involved it is possible that some of the complex phenomena of self-reversal under conditions of marked variations in density and pressure might, at least in part, be responsible. The presence, however, of a great number of com-

paratively narrow single absorption lines unaccompanied by emission bands cannot be explained in this way. Their character, as well as the law of variation of displacement with wave-length, also precludes the agency of pressure (assuming that negative displacements can be produced by pressure) and the Zeeman effect. No dependence of anomalous dispersion upon wave-length is known, even if it were adequate to produce lines of such a character with such displacements.

In some respects the Doppler effect accounts most nearly for the results observed. Motion in the line of sight would produce displacements directly proportional to wave-length and might leave the spectral lines well-defined. The velocities involved, −750 km. in the case of Nova Geminorum and Nova Aurigae, and −1500 km. for Nova Aquilae and Nova Persei, though large, are of the order found for some spiral nebulae, and not many times greater than those observed in some of the solar prominences. If the more refrangible component of the hydrogen, helium and calcium lines is considered, the velocities amount to −1500 and −2200 km. respectively. These values are for motion in the line of sight. If a generalized form of the Doppler principle is used a part or the whole of the effect might be referred to a rapid change in the thickness of stratum of gas producing the absorption, or in its refractive index. This hypothesis was suggested by W. Michelson[4] to account for the high velocities observed in solar prominences, and by Paddock[5] in the case of Nova Aquilae. Some objections to this view are the rate of change in refractive index or in thickness of the gas which would be required, especially since a decrease of index would be needed to produce displacements toward shorter wave-lengths; the harmonic relationship found among the displacements; and the relatively narrow character of the absorption lines.

The last two objections might also apply to motion in the line of sight. The suggestion, however, may be made that the absorption lines are produced in a shell of gas which is moving radially outward from the star with a high velocity. If the size of this shell is large as compared with that of the body of the star it is evident that an area of the shell only equal to that of the star would be seen in projection against the latter and would give absorption lines, and that all of the gas within this area would have large components of velocity toward the observer. This would result in comparatively narrow absorption lines. The remainder of the shell of gas would give an emission spectrum, and the combination of the widely different velocities would result in very broad bright bands with their centers nearly undisplaced. This is in accordance with observations. With these high velocities the interval of two days between the outburst of the star and the appearance of the prominent absorption spectrum would be sufficient for the gas to reach a great distance from the surface of the star. The hypothesis would, however, leave unexplained the apparent acceleration of motion during the period of observation of the absorption spectrum; and the nearly constant character of the emission bands after the disappearance of the absorption spectrum would point rather to their origin in the star itself.

The possibility of some form of dissociation is suggested by the harmonic relationship between the displacements of the components of the hydrogen lines, and the early appearance of the nebular lines in the spectra of these stars adds interest to considerations of this nature.

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[5] Paddock, G. F., *Pub. Astr. Soc. Pac., San Francisco, Cal.*, **30**, 1918, (244–249), p. 249.

ON JACOBI'S EXTENSION OF THE CONTINUED FRACTION ALGORITHM

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It has been known since Lagrange[1] that the regular continued fraction which represents a quadratic surd becomes periodic after a finite number of non-periodic partial quotients, and conversely, a regular continued fraction which becomes periodic after a finite number of non-periodic partial quotients is one root of a quadratic equation with rational coefficients. It is useless, therefore, to look for periodicity in regular continued fractions which represent cubic and higher irrationalities. To meet this difficulty Jacobi[2] undertook to extend the continued fraction algorithm as follows:

In the case of the ordinary continued fraction we are concerned with two series of numbers, A_n, B_n, (the numerators and denominators of the successive convergents) which are given by the recursion formulae

$$A_n = q_n A_{n-1} + A_{n-2}, \quad B_n = q_n B_{n-1} + B_{n-2},$$

with the initial values $A_0 = 0$, $A_{-1} = 1$, $B_0 = 1$, $B_{-1} = 0$. Jacobi considers three series of numbers, A_n, B_n, C_n, which are given by the recursion formulae

$$\begin{aligned} A_n &= p_n A_{n-1} + q_n A_{n-2} + A_{n-3}, \\ B_n &= p_n B_{n-1} + q_n B_{n-2} + B_{n-3}, \\ C_n &= p_n C_{n-1} + q_n C_{n-2} + C_{n-3}, \end{aligned}$$

with the initial values:

$$(A_{-2}, A_{-1}, A_0) = (1, 0, 0), \quad (B_{-2}, B_{-1}, B) = (0, 1, 0),$$
$$(C_{-2}, C_{-1}, C_0) = (0, 0, 1),$$

Jacobi then chose the coefficients of the expansion, p_n, q_n, so that $A_n : B_n : C_n$ should approximate $1 : \theta : a + b\theta + c\theta^2$ where θ is the real root of a cubic equa-

tion, and showed that these coefficients sometimes become periodic. Bachmann[3] showed later that with the coefficients determined by Jacobi's method periodicity will not always ensue. Berwick[4] has obtained periodic expansion for cubic irrationalities but his algorithm differs from Jacobi's.

A closer study of Jacobi's expansion reveals many remarkable points of contact with ordinary continued fractions not hitherto observed. Instead of starting with a cubic irrationality and finding an expansion to fit it, we start with a periodic expansion and find associated with it a definite cubic irrationality.

The set of three numbers (A_n, B_n, C_n) defined as above we call the nth convergent to the ternary continued fraction,

$$(p_1, q_1; p_2, q_2; p_3, q_3; \ldots\ldots\ldots)$$

The extension to four or more sets is obvious, and most of the theorems which follow hold also for quaternary and higher continued fractions. We reserve discussion of these, however.

The follwing theorem is of fundamental importance:

Theorem I: If $(A_\lambda, B_\lambda, C_\lambda)$ *is the convergent of order* λ *in the ternary continued fraction* $(p_1, q_1; p_2, q_2, \ldots)$, *and* $(A'_{\lambda'}, B'_{\lambda'}, C'_{\lambda'})$ *the convergent of order* λ' *in the ternary continued fraction* $(p'_1, q'_1; p'_2, q'_2; \ldots)$ *then the convergent of order* $\lambda + \lambda'$, $(A''_{\lambda+\lambda'}, B''_{\lambda+\lambda'}, C''_{\lambda+\lambda'})$, *of the ternary continued fraction* $(p_1, q_1; p_2, q_2; \ldots; p_\lambda, q_\lambda; p'_1, q'_1; p'_2, q'_2; \ldots; p'_{\lambda'}, q'_{\lambda'})$ *may be obtained by the formulae.*

$$\begin{aligned} A''_{\lambda+\lambda'} &= A_\lambda C'_{\lambda'} + A_{\lambda-1} B'_{\lambda'} + A_{\lambda-2} A'_{\lambda'} \\ B''_{\lambda+\lambda'} &= B_\lambda C'_{\lambda'} + B_{\lambda-1} B'_{\lambda'} + B_{\lambda-2} A'_{\lambda'}, \\ C''_{\lambda+\lambda'} &= C_\lambda C_{\lambda'} + C_{\lambda-1} B'_{\lambda'} + C_{\lambda-2} A'_{\lambda'}. \end{aligned}$$

More generally, the convergents of order $\lambda + \lambda'$, $\lambda + \lambda' - 1$ and $\lambda - \lambda' - 2$ may be obtained by the rule for the multiplication of determinants, so that

$$\begin{vmatrix} A_\lambda, A_{\lambda-1}, A_{\lambda-2} \\ B_\lambda, B_{\lambda-1}, A_{\lambda-2} \\ C_\lambda, C_{\lambda-1}, C_{\lambda-2}, \end{vmatrix} \cdot \begin{vmatrix} C'_{\lambda'}, C'_{\lambda-2}, C'_{\lambda'-2} \\ B'_{\lambda'}, B'_{\lambda'-1}, B'_{\lambda'-2} \\ A'_{\lambda'}, A'_{\lambda'-1}, A'_{\lambda'-2} \end{vmatrix} = \begin{vmatrix} A''_{\lambda+\lambda'}, A''_{\lambda+\lambda'-1}, A''_{\lambda+\lambda'-2} \\ B''_{\lambda+\lambda'}, B''_{\lambda+\lambda'-1}, B''_{\lambda+\lambda'-2} \\ C''_{\lambda+\lambda'}, C''_{\lambda+\lambda'-1}, C''_{\lambda+\lambda'-2} \end{vmatrix}$$

The proof is by induction.

Consider now the purely periodic ternary continued fraction of period k:

$$\overline{(p_1, q_1; p_2, q_2; \ldots\ldots\ldots p_k, q_k)}$$

Associated with this fraction is the following cubic equation which we shall call the *characteristic equation* of the ternary continued fraction:

$$\begin{vmatrix} A_{k-2} - \rho, & B_{k-2} & C_{k-2} \\ A_{k-1}, & B_{k-1} - \rho, & C_{k-1} \\ A_k, & B_k & C_k - \rho \end{vmatrix} = 0$$

Written at length this is

$$\rho^3 - M\rho^2 + N\rho - 1 = 0$$

where

$$M = A_{k-2} + B_{k-1} + C_k$$

and

$$N = A_{k-2}B_{k-1} - A_{k-1}B_{k-2} + B_{k-1}C_k - B_kC_{k-1} + A_{k-2}C_k - A_kC_{k-2}.$$

We have proved the following theorem concerning this equation:

Theorem II: The characteristic cubic of any periodic ternary continued fraction remains unaltered by any cyclic substitution of the partial quotients.

The proof is again by induction. Using this theorem we may prove the following recursion formulae:

Theorem III: For all integer values of $n > 3k - 1$ we have

$$\begin{aligned} A_n &= MA_{n-k} - NA_{n-2k} + A_{n-3k}, \\ B_n &= MB_{n-k} - NB_{n-2k} + B_{n-3k}, \\ C_n &= MC_{n-k} - NC_{n-2k} + C_{n-3k}. \end{aligned}$$

From Theorem III we see that the A's, B's and C's are solutions of the following linear difference equation with constant coefficients:

$$u_{x-3k} - Mu_{x-2k} + Nu_{x-k} - u_x = 0.$$

The theory of such equations is well understood (Boole's Finite Differences, p. 208). By referring to that theory we may write,

$$A_n = \Sigma K_i x_i^n \quad (i = 1, 2, 3, \ldots 3k)$$

where $K_1, K_2, \ldots K_3$ are independent of n and $x_1, x_2, \ldots x_n$ are the roots of

$$x^{3k} - Mx^{2k} + Nx^k - 1 = 0,$$

and so are the *kth* roots of the roots of the characteristic cubic.
This leads to the equation.

$$A_n = \rho_1^{n/k}\Sigma P_\nu\omega^{\nu n} + \rho_2^{n/k}\Sigma Q_\nu\omega^{\nu n} + \rho_3^{n/k}\Sigma R_\nu\omega^{\nu n}, \quad \nu = 1,2,3,\ldots k, \quad \omega^k = 1,$$

where P_ν, Q_ν, R_ν, are independent of n, and ρ_1, ρ_2. ρ_3, are the roots of the characteristic cubic. Similar equations hold for B_n and C_n

From this last result we obtain the remarkable theorem:

Theorem IV: If the characteristic cubic has one root, ρ_1, whose modulus is greater than the modulus of either of the other two roots then

$$\lim_{n\to\infty}(A_{n+k}/A_n) = \lim_{n\to\infty}(B_{n+k}/B_n) = \lim_{n\to\infty}(C_{n+k}/C_n) = \rho_1$$

If the characteristic cubic has two imaginary roots whose common modulus is greater than the absolute value of the real root then the fractions A_{n+k}/A_n, B_{n+k}/B_n, C_{n+k}/C_n do not approach any limit as n increases beyond limit.

The characteristic cubic was obtained from the last three convergents at the end of the first period. If we form a cubic in the same way from the last three convergents at the end of the second period we get what we shall call the *second characteristic cubic*. Similarly for those of higher order. The following theorem holds:

Theorem. V. The roots of the characteristic cubic of order λ *are the* λ*th powers of the roots of the first characteristic cubic.*

The proof is again by induction.

By a process similar to that by which Theorem IV was obtained we have also derived the following:

Theorem: VI. If the characteristic cubic has one root ρ_1 *whose modulus is greater than the modulus of either of the other two then the fractions* $B_n/A_n, C_n/A_n$ *and* C_nB_n *approach for* $n\to\infty$ *limits which are cubic irrationalities and are connected with the irrational number* ρ_1 *by linear fractional transformations. If the characteristic cubic has two imaginary roots whose common modulus is greater than the absolute value of the real root then these fractions do not approach any limit.*

The actual equations connecting ρ_1 with $\sigma_1 = Lim\ (B_n/A_n)$ and $\sigma_2 = Lim\ (C_n/A_n)$ and $\sigma_3 = Lim\ (C_n/B_n)$, when these limits exist are a little difficult to obtain, but turn out as follows:

$$\sigma_1 = (B_k\rho_1 + A_kB_{k-2} - A_{k-2}B_k)/(A_k\rho_1 + A_{k-1}B_k - A_kB_{k-1})$$
$$\sigma_2 = (C_{k-1}\rho_1 + C_{k-2}A_{k-1} - C_{k-1}A_{k-2})/(A_{k-1}\rho_1 + A_kC_{k-1} - A_{k-1}C_k);$$
$$\sigma_3 = (C_{k-2}\rho_1 + C_{k-1}B_{k-2} - B_{k-1}C_{k-2})/(B_{k-2}\rho_1 + B_kC_{k-2} - B_{k-2}C_k).$$

The cubic equations satisfied by σ_1, σ_2 and σ_3 may be obtained from these relations, but the algebraic work involved is tedious. It turns out that all the coefficients of the cubic in σ_1 are divisible by the determinant of the transformation connecting it with σ_1. It follows that the discriminant of the cubic in σ_1 is equal to the discriminant of the characteristic cubic multiplied by the square of the determinant of the transformation. Similar results hold for σ_2 and σ_3. The actual cubic equation satisfied by σ_1 is

$$E\sigma_1^3 + F\sigma_1^2 + G\sigma_1 + H = 0$$

where, E. F. G. H have the following values (we write for shortness A, B, C, for A_k, B_k, C_k; A_1, B_1. C_1 for $A_{k-1}, B_{k-1}, C_{k-1}$; and A_2, B_2, C_2 for $A_{k-2}, B_{k-2}, C_{k-2}$):

$$E = A^2C_1 + AA_1B_1 - AA_1C - A_1^2B,$$
$$F = A_1BB_1 + A_1BC - 2A_1A_2B + AA_1B_2 + AA_2B_1 - AA_2C - AB_1^2 + AB_1C - 2ABC_1 + A^2C_2,$$
$$G = -A_2^2B + A_2BB_1 + A_2BC + A_1BB_2 - 2ABC_2 - BB_1C + B^2C_1 + AA_2B_2 - 2AB_1B_2 + AB_2C,$$
$$H = A_2BB_2 - BB_2C + B^2C_2 - AB_2^2.$$

(The equation has been freed from the factor $A_1B^2 - AB\ (A_2 - B_1) - A^2B_2$ which is the determinant of the substitution connecting σ_1 and ρ_1)

Theorems V and VI hold word for word when the ternary continued fraction has a finite number of non-periodic partial quotients.

Some progress has been made in the problem of finding a periodic ternary continued fraction which shall be the development of a given cubic irrationality, but the results are not yet in final form.

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[2] Jacobi, *Ges. Werke*, VI, 385–426.
[3] Bachmann, *Crelle*, **75**, 1873, (25–34).
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A CHARACTERIZATION OF JORDAN REGIONS BY PROPERTIES HAVING NO REFERENCE TO THEIR BOUNDARIES

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Schoenflies[1] has formulated a set of conditions under which the common boundary of two domains will be a simple closed curve. A different set has been given by J. R. Kline.[2] Carathéodory[3] has obtained conditions under which the boundary of a single domain will be such a curve. In each of these treatments, however, conditions are imposed 1) on the boundary itself, 2) regarding the relation of the boundary to the domain or domains in question. In the present paper I propose to establish the following theorem in which *all the conditions imposed are on the domain R alone.*

Theorem. *In order that a simply*[4] *connected, limited, two-dimensional domain R should have a simple closed curve as its boundary it is necessary and sufficient that R should be uniformly connected im kleinen.*[5]

Proof. Suppose the simply connected domain R is connected im kleinen. Let M denote the boundary of R, that is to say the set of all those limit points of R that do not belong to R.

I will first show that M can not contain two arcs that have in common only one point, that point being an endpoint of only one of them. Suppose it does contain two such arcs EFG and FK with no point in common except F. Let α and β denote circles with common center at F, and with radii r_1 and r_2, respectively, such that $r_1 > r_2$ and such that E, K and G lie without α. By hypothesis there exists a positive number δ_{r_2} such that if X and Y are two points of R at a distance apart less than δ_{r_2} then X and Y lie together in a connected subset of R that lies wholly within some circle of radius r_2. Let γ denote a circle with center at F and with a radius less than one half of δ_{r_2} and also less than $r_1 - r_2$. It is clear that if two points of R are both within γ then they lie together in a connected subset of R that lies wholly within α. There

exist (fig. 1), within γ, points E', G' and K' and arcs $E'K'$ and $K'G'$ such that 1) E' and G' are on the arc EFG in the order $EE'FG'G$ and K' is on the arc FK, 2) the interval $E'G'$ of the arc EFG lies wholly within γ, 3) $E'K'$ has in common with EFG only the point E' and, in common with FK, only the point K', 4) $K'G'$ has in common with EFG only the point G' and, in common with FK, only the point K', 5) the segment FK' of the arc FK lies wholly within the closed curve J formed by the arcs $E'K'$ and $K'G'$ and the interval $E'FG'$ of the arc EFG. The arc $E'K'$ together with the interval $E'F$ of EFG and the interval FK' of FK form a closed curve J_1. The arc $K'G'$ together with the interval FG' of EFG and the interval FK' of FK form a closed curve J_2. Let I, I_1 and I_2 denote the interiors of J, J_1 and J_2 respectively. Then I is the sum of I_1, I_2 and the segment FK' of the arc FK. Let P, P_1 and P_2 denote points on the segments FK', $E'F$ and FG' respectively. The point P is a

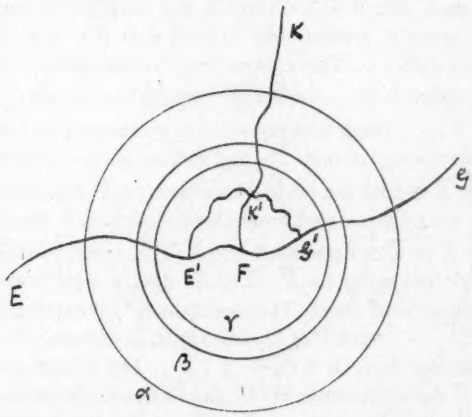

FIG. 1

boundary point of R and the region I contains P. Hence there must be points of R in I and therefore in I_1 or in I_2. The point P_1 also is on the boundary of R. It follows that there exist, within the circle γ, points of R lying either without J (and therefore without both J_1 and J_2) or within J_1. Similarly either I_2 or the exterior of J contains points of R that are within γ. Thus either both I_1 and I_2 contain points of R or only one of them contains points of R in which latter cases there must exist points of R that are within γ and without J. But if a connected point-set lies entirely within α and contains either 1) a point of I_1 and a point of I_2 or 2) a point of I_1 or I_2 and a point without J; then it must clearly contain at least one point of EFG or of FK. Therefore it can not be a subset of R. Thus the supposition that M contains two arcs EFG and FK with only the point F in common leads to a contradiction.

That M, the boundary of R, is connected is a consequence of a theorem of Hausdorff's.[6] I will proceed to show that it is connected im kleinen. Sup-

pose that it is not. Then there exists an infinite sequence $P, P_1, P_2, P_3, \ldots$ of distinct points belonging to M and a sequence of positive numbers $e, e_1, e_2, e_3, \ldots$ such that 1) $e/2 > e_1 > e_2 > e_3 > \ldots$, 2) $\text{Lim.}_{n=\infty}\, e_n = 0$, 3) the distance from P_n to P is equal to e_n, 4) if n is a positive integer there exists no connected sub-set of M containing P_n and P such that all the points of this sub-set are at a distance of less than e from P. Let K denote a circle with center at P and radius $e/2$. The point-set M contains a closed connected subset t_n that contains P_n and at least one point on K but no point without K. There does not exist an infinite sequence of distinct positive integers $\bar{n}_1, \bar{n}_2, \bar{n}_3, \ldots$ such that, for every m, $t_{\bar{n}_m}$ has a point in common with t_1. For if such were the case then $P + t_1 + t_{\bar{n}_1} + t_{\bar{n}_2} + \ldots$ would be a connected point-set containing P_1 and P and lying entirely within a circle with center at P and radius e. It follows that there exists a positive integer n_1 greater than 1 such that if $n \geqq n_1$ then t_n has no point in common with t_1. Similarly there exists n_2 greater than n_1 such that if $n \geqq n_2$ then t_n has no point in common with t_{n_1}. This process may be continued. It follows that M contains an infinite sequence of closed connected point-sets $t_{n_1}, t_{n_2}, t_{n_3}, \ldots$ $(n_1 < n_2 < n_3 < \ldots)$ such that no two of them have a point in common and such that, for every m, t_{n_m} contains P_{n_m} and at least one point on K but no point without K. Let $\overline{K}$ denote the circle whose center is P and whose radius is e_1. For every m, t_{n_m} contains a closed, connected subset $\bar{t}_m$ such that 1) every point of $\bar{t}_m$ is either on K or $\overline{K}$ or between K and $\overline{K}$, 2) $\bar{t}_m$ contains at least one point on K and at least one point on $\overline{K}$. Let K^* denote a circle concentric with K and $\overline{K}$ and lying between them. There exists on K^* a point O and a sequence of points $O_1, O_2, O_3, \ldots$ such that O_m belongs to $\bar{t}_m$ and such that O is a limit point of the point-set $O_1 + O_2 + O_3 + \ldots$. Let K' denote a circle lying between K and $\overline{K}$ and with center at O. Let $2h$ denote its radius. Let K'' denote a circle with the same center and with a radius less than h and also less than $\delta_h/2$. There exist within K'' four points $O_{m_1}, O_{m_2}, O_{m_3}$ and O_{m_4} of the set $O_1, O_2, O_3, \ldots$. Of these four points, two, A_1 and A_3, are separated from each other on K^* by the other two, A_2 and A_4. For each i $(1 \leqq i \leqq 4)$ let a_i denote that one of the point-sets $t_{m_1}, t_{m_2}, t_{m_3}$ and t_{m_4} to which the point A_i belongs. For each i $(1 \leqq i \leqq 4)$ there exists, within K'' (fig. 2), a circle K_i, with center at A_i, that neither encloses nor contains a point of any of the sets a_1, a_2, a_3, a_4, except a_i. The circles K_1 and K_3 respectively enclose points B_1 and B_3 belonging to R. Every closed connected point-set that contains both B_1 and B_3 and lies between K and $\overline{K}$ must contain a point either of a_2 or of a_4. But there exists a connected subset of R that contains both B_1 and B_3 and lies wholly with K'. Thus the supposition that M is not connected im kleinen has led to a contradiction.

Since M is limited, closed, connected and connected im kleinen, it follows[7] that every two points of M can be joined by a simple continuous arc lying wholly in M. The point-set M contains a countable subset N of points

$P_1, P_2, P_3, \ldots$ such that every point of M is a limit point of N. For each n, P_n can be joined to P_{n+1} by a simple continuous arc P_nP_{n+1} lying entirely in M. In view of the fact that if M contains two arcs with only one point in common, that point must be an end-point of each of them, it is clear that, for every n, $P_1P_2 + P_2P_3 + \ldots + P_{n-1n}P$ is either a simple closed curve or a simple continuous arc. It is clear that if, for some n, it is a simple closed curve, then this curve is identical with M. Suppose on the other hand, that, for every n, it is a simple continuous arc A_nB_n, the notation being so assigned that, in the order from A_n to B_n on the arc A_nB_n, every A_i precedes every B_j $(1 \leqq i \leqq n, 1 \leqq j \leqq n)$, Let N^* denote the point-set constituted by the sum of all the arcs $A_1B_1, A_2B_2, A_3B_3, \ldots$ If $P_1, P_2, P_3, \ldots$ is a

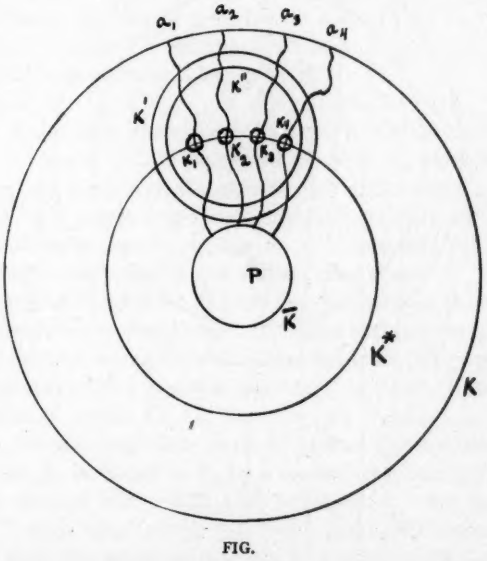

FIG.

set of points such that for every n, P_n follows B_n on some arc of the set A_1B_1, $A_2B_2, \ldots$ then the set $P_1, P_2, P_3, \ldots$ does not have more than one limit point. For suppose there exists such a set with two distinct limit points O_1 and O_2. Then if C_1 and C_2 are two distinct circles with center at O_1 and such that O_2 is without each of them, there clearly exists an infinite set of arcs G (Fig. 3) such that 1) each arc of G is, for some n, i and j $(1 \leqq i \leqq n, 1 \leqq j \leqq n)$ a sub-interval of the interval B_iB_j of the arc A_nB_n, 2) no two arcs of G have a point in common, 3) each arc of G lies entirely between C_1 and C_2 except that one of its endpoints is on C_1 and the other one is on C_2. But, in the course of the above proof that M is connected im kleinen, it was shown that M does not contain such a set of arcs.

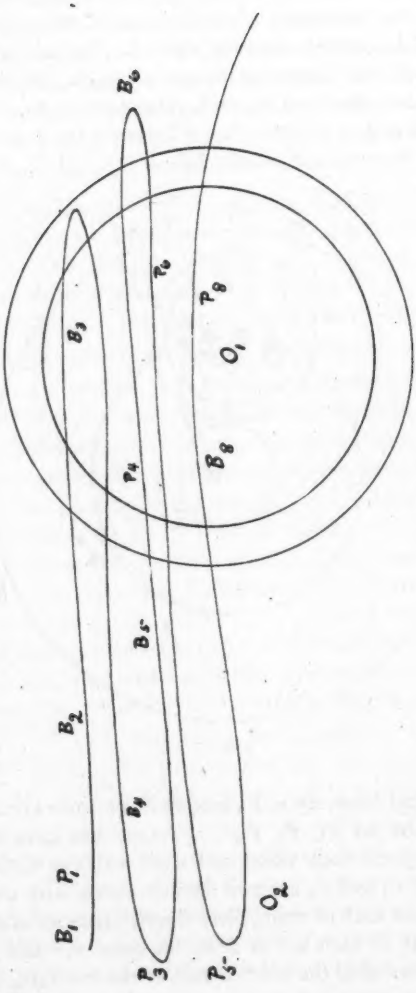

FIG. 3

Similarly if $P_1, P_2, P_3, \ldots$ is a set of points such that, for every n, P_n precedes A_n on some arc of the set $A_1B_1, A_2B_2, \ldots$, then the set $P_1, P_2, P_3, \ldots$ can not have more than one limit point. It is clear that at least one of the sets $A_1, A_2, A_3, \ldots, B_1, B_2, B_3, \ldots$ is infinite. Otherwise N^*, and therefore M, would be a simple continuous arc, which is impossible in view of the fact that it is the boundary of a limited domain. There remain two conceivable cases. Either 1) the sets $A_1, A_2, A_3, \ldots$ and $B_1, B_2, B_3, \ldots$ are both infinite or 2) one is finite and the other infinite. Suppose they are both infinite. Consider the facts that 1) no set with the properties indicated above for $P_1, P_2, P_3, \ldots$ has more than one limit point, 2) no simple continuous arc is the boundary of a limited domain and, 3) M does not contain two arcs with only one common point, that point being an end-point of only one of them. In view of these facts it is clear that $A_1, A_2, A_3, \ldots$ and $B_1, B_2, B_3, \ldots$ have a common limit point O and that the point-set $N^* + O$ is a simple closed curve, identical with M.

Suppose the set $A_1, A_2, A_3, \ldots$ is infinite while $B_1, B_2, B_3, \ldots$ is not. With the aid of the same three considerations, it is clear that in this case $A_1, A_2, A_3, \ldots$ has as its only limit point the point B_m where m is a positive integer such that, for every n greater than m, B_n coincides with B_m. In this case the pount-set N^* is a simple closed curve, identical with M. Of course a similar argument applies in case $A_1, A_2, A_3, \ldots$ is finite and $B_1, B_2, B_3, \ldots$ is infinite. Thus in every case M is a simple closed curve.

I will now proceed to establish the converse proposition that *every Jordan region is uniformly connected im kleinen.* Suppose that, on the contrary, there exists a closed curve J whose interior I does not have this property. Then there must evidently exist a positive number a, a point O on J and two infinite sequences of points $X_1, X_2, X_3, \ldots Y_1, Y_2, Y_3, \ldots$ lying in I, such that O is the sequential limit point of each of these sequences and such that for no n can X_n be joined to Y_n by a connected subset of I that lies entirely within a circle K with center at O and radius a. But there exists[8] a closed curve J^* containing O such that every point of J^* belongs either to J or to K and such that every point within J^* is within both J and K. It is clear that for some n the points X_n and Y_n are both within J^*. But the interior of J^* is a connected subset of I and also of the interior of K. Thus the supposition that I is not uniformly connected im kleinen has led to a contradiction.

[1] Schoenflies, A., *Göttingen, Nachr. Ges. Wiss.*, 1902, (185).

[2] Kline, J. R., *Bull. Amer. Math. Soc., New York*, **24**, 1918, (471). One of Kline's conditions is that the common boundary of the domains in question should be connected 'im kleinen.'

[3] Carathéodory, C., *Math. Ann., Leipzig*, **73**, 1912–13, (366).

[4] In space of two dimensions, a domain is said to be *simply connected* if it is connected and contains every limited point-set whose boundary lies in it.

[5] A point-set M is said to be *connected 'im kleinen'* if for every point P of M and every positive number e there exists a positive number δ_{eP} such that if X is a point of M at a dis-

tance less than $\delta_{e\beta}$ from the point P, then X and P lie together in a connected sub-set of M every point of which is at a distance of less than e from the point P. The set M is said to be *uniformly* connected im kleinen if for every positive number e there exists a positive number δ_e such that if P_1 and P_2 are two points of M at a distance apart less than δ_e then they lie together in a connected sub-set of M every point of which is at a distance of less than e from P_1. Cf. Hahn, H., *Jahresber. D. Math. Ver., Leipzig*, **23**, 1914, (318–322).

[6] Hausdorff, F., *Grundzüge der Mengenlehre*, Veit & Co., Leipzig, 1914.

[7] Cf. my paper, A theorem concerning continuous curves, *Bull. Amer. Math. Soc.*, **23**, 1917, (233–236).

[8] Cf. Theorem 43 of my paper, On the foundations of plane analysis situs, *Trans. Amer. Math. Soc., New York*, **17**, 1916, (131–164). I take this opportunity to correct an error in the statement of Theorem 44 of this paper. In this statement the upper 'interior' and the two upper 'without's are to be omitted.

A BIOMETRIC STUDY OF HUMAN BASAL METABOLISM

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Communicated October 8, 1918

Investigators are now generally agreed that the metabolism, expressed in terms of calories per unit of time, of the normal subject shall be taken as a basis of comparison in the investigation of all the special problems of human nutrition, for example, that of the requirements for muscular activity, that of the influence of specific diseases or of the level of nutrition upon metabolism, that of the change of metabolic activity with age, and so forth. Critical investigations in both European and American laboratories have shown that the gaseous metabolism is so affected by various factors that determinations which are to serve as a standard must be made under very exactly controlled conditions. It is not merely necessary to devise apparatus in which the physical difficulties of direct calorimetry (or of the exact measurement of gaseous exchange from which heat production may be computed) are overcome. Certain biological factors must be ruled out. Those of greatest importance as sources of experimental error are muscular activity and the stimulatory action of recently ingested food. The heat production of the individual in a state of complete muscular repose 12–14 hours after the last meal, i.e., in the postabsorptive condition, has been called the basal metabolism.

For a decade the Nutrition Laboratory has been engaged in carrying out a series of determinations of basal metabolism in normal human individuals of both sexes and of widely different ages. These have been made with all the modern refinements of method and manipulation. The subjects were in presumably good health. All those with febrile temperature were discarded. All were in the postabsorptive condition. Perfect muscular repose during the short periods required for indirect calorimetry was assured by an automatic record of all movements, even those imperceptible to a trained observer.

Measurements on 136 men, 103 women and 94 new-born infants have been analyzed biometrically with the purpose of determining the statistical constants (means, standard deviations, coefficients of variation, coefficients of correlation, and regression equations) which may serve as standard constants in work on human metabolism until those based on more extensive series of data are available. In carrying out this analysis we have proceeded on the conviction that the widest possible usefulness of laboratory investigations of human metabolism will result from basing measurements upon individuals who are in presumably good health, but who are otherwise typical of the population at large. It is only when the subjects used for experimentation are representative of the general population in type, variability and correlation that results of laboratory research upon limited series of individuals may be safely generalized for rationing or for other practical social applications. Statistical tests of the suitability of the series used in the present investigation have been applied.

The relationship between certain of the physical and physiological measurements of the individual and between the various physiological measurements has been determined. Our series of data show practically no relationship between basal or minimum pulse rate and stature or body weight in adults. There is a low but significant positive correlation between minimum or basal pulse rate and gaseous exchange and heat production. The Nutrition Laboratory has long emphasized the correlation between pulse rate and metabolism in the same individual, that is, the intra-individual correlation between the rate of the heart beat and the amount of the katabolism. Here, however, we are dealing with the problem of the relationship between the minimum or basal pulse rate of a series of individuals and their basal metabolism—that is, with inter-individual correlation.

There is a substantial correlation between stature and heat production. The correlation between body weight and heat production is higher being of the order $r = 0.75$ to $r = 0.80$ in the new-born infants, of the order $r = 0.80$ in men and $r = 0.60$ in women. Analysis by means of partial correlation coefficients indicates that both stature and body weight have independent significance as bases for the prediction of the basal metabolism.

The change in basal metabolism with age during the period of adult life has been shown to be well represented by the linear equations,

For men ($N = 136$)

$$h = 1823.80 - 7.15, a,\ h_k = 28.703 - 0.112\, a,\ h_d = 1022.17 - 3.60\, a.$$

For women ($N = 103$)

$$h = 1420.47 - 2.29\, a,\ h_k = 28.308 - 0.124\, a,\ h_d = 942.25 - 2.96\, a.$$

where h = total heat production in calories per 24 hours, h_k = calories per kilogram of body weight, h_d = calories per square meter of body surface as estimated by the Du Bois height-weight chart. Thus in men the daily heat

production decreases about 7.15 while in women it decreases about 2.29 calories per year. Women are smaller than men and have a lower heat production. When the decrease in metabolism with age is expressed in calories per kilogram of body weight or in calories per square meter of body surface, the results for the two sexes are much more nearly identical.

The problem of the difference in the metabolism of men and women, dealt with in the past by a number of writers, has been reconsidered on the basis of the larger series of data now available. The average daily (24 hours) basal heat production of men is 1632 calories whereas that of women is 1349 calories. Thus women have an average daily heat production about 300 calories less than that of men. But women are smaller than men. If correction for body size be made by expressing heat production in calories per kilogram of body weight, it is 25.7 calories in the 136 men as compared with 24.5 calories, or 1.2 calories per kilogram less, in the 103 women. On the basis of heat production per square meter of body surface as estimated by the Du Bois height-weight chart the men show an average daily heat production of 925 calories as compared with 850 calories, or 75 calories less, in the 103 women. The most critical test of the difference of men and women in the level of metabolism is that furnished by a modification and extension of the selected group method of Benedict and Emmes. In the new method the control values for the several groups of women are not the empirical constants for men of as nearly as possible like stature and body weight but are determined from equations taking into account stature, weight and age in all the available data for men. Analysis shows that, however expressed, the metabolism of American women is lower than that of the men. Our results show that the differentiation of the sexes is not evident in infancy. They do not confirm the conclusion of Sondén and Tigerstedt that the difference between men and women tends to disappear with age. Instead we find the difference in the metabolism of men and women well-marked throughout the period of adult life.

The validity of the so-called body surface law, according to which metabolism is proportional to the superficial area of the individual, i.e.,

$$h = a\bar{h}_a$$

where a = superficial area and $\bar{h}_a$ = mean heat production per unit of time per square meter of body surface in a standard series, has been critically tested. It has been shown that the supposed proofs of its validity hitherto adduced are erroneous. Heat production is not 'proportional to body surface but not to body weight' as has been asserted to be the case, but is highly and about equally correlated with both body weight and body surface. It has been shown that as a basis for predicting the heat production of a subject the above relationship is less satisfactory than multiple regression equations involving stature, weight and age. Thus the 'body surface law' is deprived of its unique significance as a basis for the prediction of the me-

tabolism of an unknown subject. An analysis of the data of actual experimentation on subjects at changing levels of nutrition shows that the changes in metabolism are not proportional to those in body surface. Surface area may not be looked upon as a determining factor in basal metabolism.

The closest prediction of the daily heat production of a subject can be made by the use of the multiple regression equations,

For men, $h = 66.4730 + 13.7516\,w + 5.0033\,s - 6.7550\,a$

For women, $h = 655.0955 + 9.5634\,w + 1.8496\,s - 4.6756\,a$

where h = total heat production per 24 hours, w = weight in kilograms, s = stature in centimeters, and a = age in years. These equations have been tabulated for values of weight from 25.0 to 124.9 kgm., for stature from 151 to 200 cm., and for age from 21 to 70 years, so that the most probable basal metabolism of an unknown subject may be easily determined.

Such tables should render service in clinical and other fields of applied calorimetry. Their usefulness has been demonstrated in testing the typical or atypical nature of series of metabolism measurements, in investigating the differentiation of the sexes with respect to metabolic activity, of the metabolism of athletes as compared with non-athletic individuals, and of individuals suffering from disease.

The detailed measurements and statistical constants, with full discussions of pertinent literature, are about to appear in Publication No. 279 of the Carnegie Institution of Washington.

SEX AND SEX INTERGRADES IN CLADOCERA

By Arthur M. Banta

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Communicated by C. B. Davenport, October 18, 1918

There is probably no one factor in the biological world of greater interest and importance than sex.

Most plants are dioecious, producing the reproductive cells of both sexes within the same individual organism. Several lower animals are normally hermaphroditic but by far the larger part of the forms in the animal world are unisexual.

So general is unisexuality in animals and so little thought do we in general give to the comparatively few normally hermaphroditic forms that we are accustomed to think of maleness and femaleness as opposed and mutually exclusive states which cannot coexist in the same organism. We are accustomed to think of maleness as indicating the possession not only of a sperm-producing gland and accessory reproductive structures but also the possession of the peculiar secondary sex character—structural, physiological, and even psychological and behavior characteristics. The term female implies pro-

nounced characteristics contrasting with those of a male on these several points. In other words maleness and femaleness are generally assumed to indicate definite and precise alternative and opposing states only one of which may obtain in the same individual organism.

With unisexual forms known deviations from the supposed mutually exclusive conditions of maleness and femaleness were until recently confined to a comparatively few cases of hermaphroditism and gynandromorphism. Such cases have been defined as sex mosaics—definite gonads or portions of the gonads or other parts of the body being described as distinctly of one or of the other sex.

However, there are at least three known cases of the common occurrence of unmistakable intermediate sex forms—sex intergrades. These are Riddle's hybrid pigeons,[1] Goldschmidt's hybrid gypsy moths[2] and the writer's Cladocera material. These are not sex mosaics but sex intergrades.[3] That is to say, they are not fully male in certain definite portions of the body and fully female in other portions but frequently as a whole and (in the writer's material) almost always in certain parts they clearly possess both femaleness and maleness—they are as a whole and by parts distinctly intermediate as regards sex.

In the Cladocera material there sometimes occurs an individual which might very readily be considered a sex mosaic, inasmuch as its complement of secondary sex characters consists of some apparently fully male and some fully female characters. But the majority of these secondary sex characters are obviously intermediate between the fully female and the fully male character, and there are comparatively few of the sex intergrades which do not have one or more such intermediate sex characters. These intergrading sex characters clearly indicate that we have to do not with sex-mosaics but with sex intergrades.

In Cladocera the population ordinarily consists entirely of females and reproduction is by means of parthenogenetically developing eggs. Occasionally males appear and some females produce the less usual type of egg which must be fertilized in order to develop. This occasional sexual reproduction has given rise to the notion that there is an innate sexual cycle in these forms.

In all the many lines of the writer's stock however, previous to the appearance of the sex intergrade strains, males were seen only two or three times and in as many lines.[4] Though no sexual reproduction has occurred in any case the various lines continue to reproduce with their original vigor. Hence as applied to this material the supposed innate sexual cycle seems quite an unwarranted assumption.

In the writer's stock previous to the appearance of the recognized sex intergrade strains there were a few individuals of one strain of Daphnia longispina which may have been sex intergrades. These individuals failed to reproduce but it is probable that they were really sex intergrades and that

there would have been intergrades among their offspring if they had reproduced at all.

Undoubted sex intergrades were first found and propagated in the writer's stock in one of the strains of Simocephalus vetulus. None have been seen in any strain of this species except in direct descendants of the initially discovered sex intergrade mother. Great numbers of Simocephalus vetulus have been examined microscopically especially in the last sixteen months and while normal males have been found on occasion, no sex intergrades have been discovered. This is true in spite of the fact that the sex characters are the characters especially scrutinized and that in the aggregate many thousands of Simocephalus vetulus have been examined. Hence in Simocephalus vetulus the occurrence of clearly marked sex intergrades is by no means to be considered a frequent phenomenon.

In Daphnia longispina, however, sex intergrades have been discovered in all three of the strains of line 768, and we now have in the laboratory well established strains of sex intergrades from two of these three strains. Sex intergrades have been found also in two of the three other laboratory lines of this species. Coupled with the fact that the observation of probable sex intergrades at an earlier time was also in this species, the occurrence of sex intergrades in all except one of the six strains of Daphnia longispina in the laboratory, seems to indicate that for this species the production of sex intergrade strains is not such an unusual phenomenon. However, one significant fact should not be overlooked, namely, that except for close scrutiny of the cultures including microscopic examination of great numbers of individuals the occurrence of intergrades would not have been suspected.

Though in recent months males have been found in all except one strain of all the stock of the seven species of Cladocera reared in the laboratory no intergrades have been discovered in either Daphnia pulex, Simocephalus serrulatus, or in three species of Moina, or in Simocephalus vetulus except in descendants of the original sex intergrade mothers. The sexual characters of thousands of individuals of each of these species have been microscopically examined.

Within the stock in the laboratory it then seems fairly clear that the occurrence of sex intergrades is quite unusual, though intergrades have been found in most of the strains of Daphnia longispina.

The sex intergrade strain of Simocephalus vetulus originated in October, 1915, in line 740 in its 131st laboratory generation during a period of conditions of poor nutrition in the stock due to unsatisfactory food.

The secondary sex characters and other matters relating to this intergrade strain have been discussed in some detail in another paper[5] (Banta, 1916) and need not be considered further here.

The sex array is extensive. There occurs almost every combination of male and female primary and secondary sex characters. This coupled with the fact that most of the secondary sex characters occur very frequently in an

intermediate condition serves to make the sex array in Simocephalus very extensive indeed. In fact a precise classification is quite impossible and only an extremely relative classification is at all feasible.

Since the origin of sex intergrades in line 740, the sex intergrade strains have descended for nearly three years (about 57 generations). The character of the stock seems unchanged—the sex array and proportions of the various apparently pure sex forms and intergrades of different sorts continues as it was when the intergrade stock first appeared.

The sex intergrades in Daphnia longispina were first observed in May, 1917. They appeared in one of the three strains of line 768. This strain was not passing through a period of unfavorable conditions at that time nor was there anything unusual observed in its behavior except the occurrence of sex intergrades. It is indeed not certain that intergrades may not have occurred sparingly for a few generations before they were discovered. The first intergrade mothers noted in this strain produced many sex intergrades among their offspring. Several intergrade strains were at once isolated from this stock and placed under observation.

The secondary sex characters in Daphnia longispina are as follows: (1) *Body size*—the females are larger than the males; (2) *Character of the head outline*—the ventral margin of the head in the female slopes almost uniformly to the tip of a pointed rostrum or beak while in the male the beak is absent; (3) and (4) *Characters of the first (rudimentary) antennae*—the paired female first antennae are represented only by slight eminences from which arise a few sensory stylets, while in the male the first antennae are movable structures three-fifths as long as the head. At its distal end each male antenna is armed with a stout bristle in addition to the sensory stylets possessed by the female; (5) and (6) *Character of the breast margins*—the female ventral carapace margins are almost uniformly rounded from the anterior portion backward. In the male these margins are angulated almost to 90 degrees in the region nearest the head. Further in the region of this angle these margins are fringed with hairs in the male while none occur in the female; (7) and (8) *Character of the first legs*—in the female the terminal joint of each of the first pair of legs is not armed with a hook, while this segment in the male bears a stout hook.

That these characters are distinctive of the two sexes is shown by the fact that they occur practically without deviation in wild stock, and in females[6] and males of the stock not producing intergrades, as well as in the extremes of the series in the sex intergrade strains.

The array of sex intergrades in Daphnia longispina is less extensive than in the sex intergrade strains of Simocephalus vetulus in that male sex intergrades (i.e., intergrades with testes) are almost or quite lacking and further that males are extremely scarce in the sex intergrade strains of this species. That is to say that toward the male end of the series where should occur numbers of male intergrades and ostensibly normal males—if the sex array

were complete and uniform—the numbers of male intergrades and apparently fully male individuals are few and the series is not at all diverse. On the other hand with the Simocephalus vetulus sex intergrade stock normal males are abundant and male intergrades are common in occurrence. In other words the sex intergrade strains of Daphnia longispina are more female and correspondingly less male than those of Simocephalus vetulus.

In another manner the sex intergrades of Daphnia longispina differ from those of Simocephalus vetulus. Each of the several secondary sex characters in Daphnia longispina is subject to intermediate development and occurs in all intergrading stages from the fully female to the fully male secondary character; whereas some of the secondary sex characters in Simocephalus vetulus are not such as to readily show so wide a range of intermediate conditions.

One rarely finds a Daphnia longispina intergrade which has its full complement of secondary sex characters—each character apparently fully male or fully female. The vast majority of the Daphnia longispina intergrades have at least three (of a total of eight) secondary sex characters distinctly intermediate between the male and female in point of sex significance, while frequently all of the secondary sex characters partake of the intermediate condition.

With the sex intergrade strains of both Simocephalus vetulus and Daphnia longispina the character of offspring is somewhat correlated with the secondary sex characters of the mother. The more maleness the female intergrade possesses the more highly male in general will be the character of the offspring. In most cases the relative amount of maleness and femaleness possessed by the different individuals of a brood of young is extremely variable; but ordinarily if the mother is highly intergrade in several characters the young, while quite variable will also on the average be relatively highly male in their characteristics. On the other hand a female from a sex intergrade strain who herself shows little or no evidence of maleness will ordinarily produce young with few or slight male characters, though the young are on the average usually more male than the slightly intergrade mother herself.

An extremely intergrade mother, whose secondary sex characters are all largely or fully male, is in most cases sterile or nearly so. This is notably true of the Simocephalus vetulus sex intergrades in which a female intergrade with a full complement of male secondary sex characters has not been known to reproduce. On the other hand a female intergrade with few male or only slightly male secondary sex characters is usually highly productive of young.

Sex intergrade production would seem to be the result of a disturbed balance, a condition which—obviously in many individuals and probably in all individuals, *at least* of the sex intergrade strains—is a struggle of two nearly equal factors or sets of factors, the one making for maleness, the other for femaleness. The result of this struggle of factors is individuals ostensibly male in part and female in part and obviously intermediate in part—but as a whole distinctly intermediate in sex characters.

The point of perhaps greatest importance lies in the findings of sex intergrades in a number of lines of a second species of Cladocera—in fact in five out of six lines of that species which have been reared in the laboratory. In addition De la Vaulx records[7] what are almost certainly such intergrade individuals in Daphnia atkinsoni. These extensions of the known occurrences of sex intergrades among Cladocera indicate that a condition of sex intergradedness in Cladocera is less unusual than the writer formerly supposed—that maleness and femaleness are even less exclusive phenomena so far as indicated by morphological characters in Cladocera than was believed. In this material the disturbances of the balance of the factors or sets of factors making for sex is less unusual than would seem probable if maleness and femaleness were really generally mutually exclusive.

From such clear cases of sex intermediates one wonders if maleness and femaleness are really mutually exclusive in those Cladocera individuals which morphologically show no unlike sex characters. It seems extremely probable that they are not, particularly in view of the fact that in sex intergrade strains apparently normal females frequently produce young of widely divergent types of sex intergrades. Even in the 'normal' strains one is certainly justified in thinking that maleness and femaleness are not complete and mutually exclusive states but that in these apparently normal sex forms, too, sex is also relative—differing from the so-called sex intergrades not in kind but merely in degree, not qualitatively but quantitatively.

With the relativity of sex so emphatically shown in hybrid pigeons, in hybrid moths and in different species of Cladocera one wonders if the relativity of sex ends with pigeons, gypsy moths and water fleas. There seems every reason to think it does not. We are coming to the time when it would seem imperative to revise our notions of the fixity of sex. The clear cases of sex intergrades or sex intermediates just referred to seem no more nor no less illustrations of the relativity of sex than one sees in the 'crowing hen' and the 'sitting cock' or in the masculine woman and in the man who in almost intangible physical characteristics, in speech, in dress, in tastes and habits of behavior, and in methods of thought reveals himself as lacking in something which makes for the fully equipped male and as possessing qualities ordinarily recognized as characteristics of the female.

Further it does not seem necessary to suppose that relativity of sex is restricted to cases in which its very conspicuousness forces itself upon our unwilling attention in opposition to our fixed conceptions of maleness and femaleness as complete, opposed, and mutually exclusive phenomena. Indeed the more reasonable supposition is that sex is always relative, that while most sexual individuals of whatever species are prevailingly male or prevailingly female every individual may have something of the other sex intermingled with its prevailing sexual characters.

[1] Riddle, Oscar, *Carnegie Inst. Washington Year Book*, **12**, 1913, (322); also *Amer. Nat.* **50**, 1916, (385–410).

[2] Goldschmidt, R., *Zs. ind. Abs.-Vererbungslehre*, **7**, 1912, (1–62); also these PROCEEDINGS **2**, 1916, (53–58).

[3] Called sex intermediates by Riddle; intersexual forms by Goldschmidt.

[4] There is one reference in the literature to androgynous Cladocera (in Daphnia atkinsoni). Judging from De la Vaulx's description these individuals, which he called gynandromorphs, were almost certainly sex intergrades.

[5] Banta, A. M., these PROCEEDINGS, **2**, 1916, (578–583).

[6] The writer used the terms female and male with the mental reservation that inasmuch as femaleness and maleness are now definitely known to be relative in some cases they may be relative in *all individuals* and that the terms female and male are themselves to be considered relative not only in Cladocera, pigeons and moths but perhaps also in all animal and plant forms in which sex is known to occur.

[7] Vaulx, R. de la, *Bull. Soc. Zool. France*, **40**, 1916, (102–104, 194–197,

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ON THE METHOD OF PROGRESSION IN POLYCLADS[1]

BY W. J. CROZIER

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Communicated by E. L. Mark, October 29, 1918

Turbellarians are able to make progress through the water by means of muscular movements of the body as a whole, or of its lateral extensions; their creeping progression on a solid substratum, however, has usually been attributed to the action of cilia. According to Stringer (1917),[2] the locomotion of planarians is effected by muscular contractions, which may be organized after the manner of the locomotor wave upon the foot of a monotaxic gastropod (cf. Parker, 1911),[3] the ciliary activity taking no necessary part in the locomotion. Some observations, which may here be briefly noted, tend to confirm the nature of this finding, and add to the variety of known muscular creeping movements in turbellarians.

One species of Leptoplana, occurring at Bermuda in moderate numbers, differs from the more frequently encountered L. lactoalba Verr., approaching more nearly the form L. lactoalba var. tincta Verr. It is found on the under surfaces of stones, near high water level, and is commonly about 3.5 cms. long. If, out of water, a stone bearing one of these leptoplanas is turned over, exposing the animal to light, it creeps about upon the moist surface. The worm also creeps rapidly under water, and in addition is a vigorous swimmer. It has usually been believed that in Leptoplana "creeping is a uniform gliding movement, caused by the cilia of the ventral surface, aided perhaps [how?] by the longitudinal muscle layer of this surface" (Gamble, 1901, p. 10).[4] While this may very well seem to be the case in L. tremellaris (Gamble, loc. cit.), and in several other species which I have observed, it is distinctly not true of the form which I may refer to as L. 'tincta.' The ventral surface of this platode is richly ciliated, and in creeping it deposits an appreciable slime-track, such as that in which the cilia of triclads have

been supposed to cause creeping owing to their beatings. But the muscular operations involved in the creeping are of so obvious a kind as to be quite unmistakable. These movements are the same whether the worm is in water or out of it, whether it is creeping upon the surface film or on submerged objects.

The essential feature of the progression is illustrated in Figures *A*, *B*, *C*. Creeping is rapid, as quick as 5 mm. per second. One side of the body at the anterior end is lifted from the substratum, thrust 4 to 5 mm. forward, and firmly attached to the substratum; then the opposite side is thrust forward in a similar way. On each side of the body a wave is thus initiated, which may travel the whole length of the animal or may go only one-half to one-third the distance toward the tail. The edge of the body is thrown into wavy wrinkles; these progress toward the posterior end, which is reached in 3 to 4 seconds. The succession of these waves is rapid, so that 4 to 5, or more, may be present at one time on each side of the body. This rapidity makes it difficult, except at the anterior end itself, to be sure in all cases of the truly alternate relation of the waves on the two sides; but in many instances they undoubtedly remain alternate, especially in slow creeping. The shuffling movement of the worm under these circumstances recalls vividly that of a retrograde alternate ditaxic gastropod foot.[3]

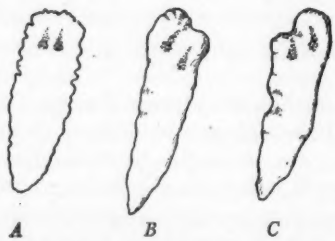


FIG. 1 ILLUSTRATING THE METHOD OF CREEPING IN A SPECIES OF LEPTOPLANA. DIAGRAMMATIC.

A, at rest; *B*, *C*, the initation of alternate waves of body contraction which are responsible for creeping. (Natural size.)

When Leptoplana 'tincta' is induced to creep with special rapidity, the body-waves become more pronounced, and although they remain distinctly alternate and 'ditaxic' in their origin at the anterior end of the animal, they may fuse to form a single retrograde, 'monotaxic' wave after about a third of the worm's length has been traversed. The locomotor wave thus becomes more allied to that developed in swimming, for although some other leptoplanas swim through the water by means of winglike flappings of the lateral extensions of the body,—a process analagous to the parapodial swimming of Aplysia—in L. 'tincta' the swimming movement involves a sinuous longitudinal 'gallop' of the body as a whole.

During progression on a surface, the periphery of the body is the part vitally concerned, for the animal may be transversely arched in such a way that, save at the very anterior end, the periphery is the only part actually in contact with the substratum. The attachment of the peripheral edge of the worm is produced by local suction. Although slime is secreted there, the manner in which the attachment is made to a small surface, e.g., a pencil point, and the way this attachment may be instantaneously released when the worm begins to creep, force one to believe that the edge of the body is not being held in place by sticky slime. This use of the edge of the 'foot' is similar to that found in Chromodoris, and perhaps in other large midibranchs (Crozier and Arey, 1918).[5]

At rest, the outline of L. 'tincta' is usually thrown into 'stationary waves.' These waves may appear truly opposite, not alternate, especially at the anterior end of the worm. Occasionally, at the beginning of creeping, a 'monotaxic' movement is executed, but this operation is characteristically 'ditaxic,' the lateral halves of the body contracting in alternate sequence.

With one of the several species of Pseudoceros which are found inhabiting colonies of the tunicate Ecteinascidia turbinata Herd., I have been able to make observations which show that muscular creeping operations are probably general among polyclads. In this form also the locomotor waves are essentially alternate, 'ditaxic,' and retrograde, the axial region of the body being usually arched away from the substratum, thus separating the body into halves. The wave is a region lifted from the substratum. Two waves may be present on each side, simultaneously. Here, as in the Leptoplana, *when the muscular waves are absent, no creeping progression can be detected.* In the Pseudoceros the waves are especially well seen when the animal is creeping on the surface film. A rippling movement of the outline of the body usually accompanies the 'body-waves,' and when viewed from above this is the only contractile operation to be seen. The peripheral rippling may, however, be very slight or even absent altogether.

Neither of these flat-worms has been observed to creep in any but an anterior direction.

These observations tend to show that in turbellarians generally, muscular operations analagous to those executed by the foot of chitons and of gastropods are essentially concerned in creeping locomotion.

[1] Contributions from the Bermuda Biological Station for Research. No. 89.

[2] Stringer, C. E., 1917, These PROCEEDINGS, 3, 691–692.

[3] Parker, G. H., 1911, *J. Morph., Wistar Inst., Phila.*, 22, (155–170).

[4] Gamble, F. W., 1901, *The Cambridge Nat. Hist.*, 2, p. 1–96, 47 fig., London

[5] Crozier, W. J., and Arey, L. B. *The sensory behavior of Chromodoris zebra.* (In press).

THE PHYLOGENY OF THE ACORN BARNACLES

By Rudolf Ruedemann

State Museum, Albany, N. Y.

Communicated by J. M. Clarke, October 29, 1918

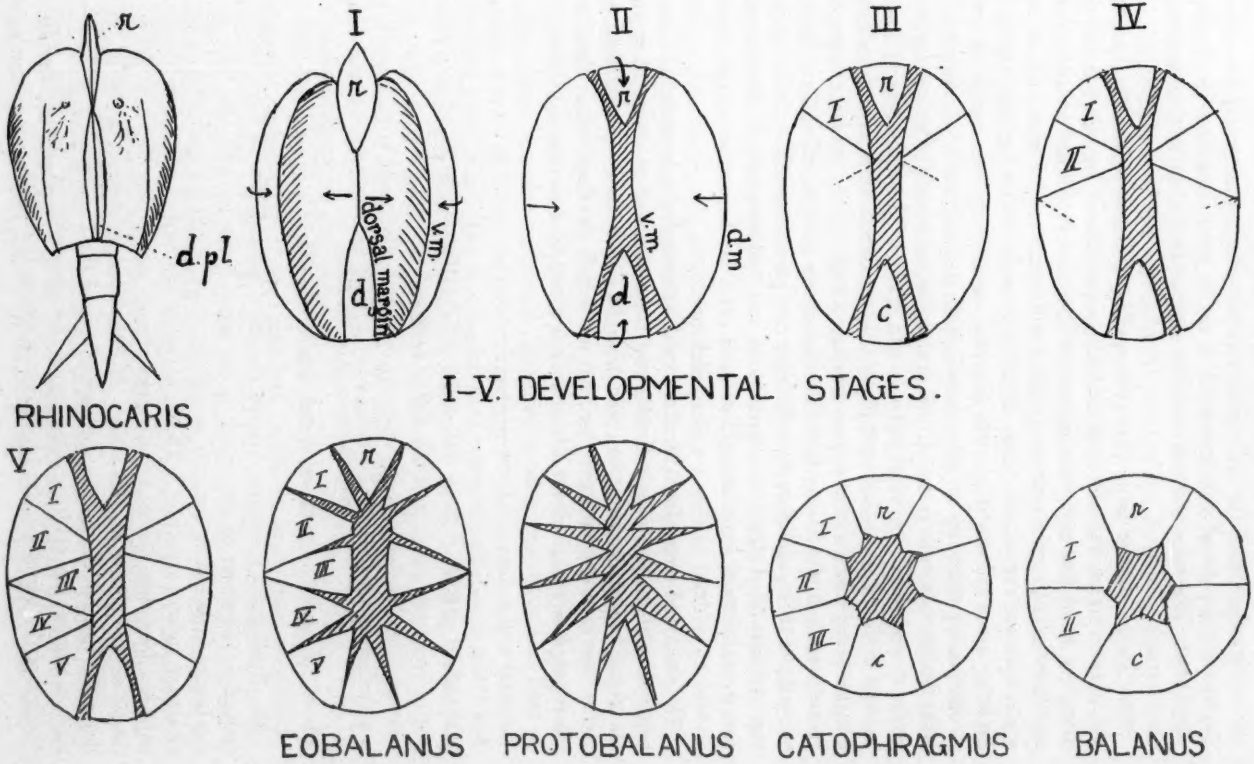
The Acorn Barnacles of Balanidae represent the most advanced stage of regression attained in the Cirripedes through adaptation to a sessile life. Darwin regarded them as derived from the Lepadidae or Goose Barnacles by the loss of the peduncle, and this view has been generally accepted. The whole order of Cirripedia is interpreted by some students as derived from the Copepoda, but others find its ancestors in the ostracodes, because of the bivalved 'Cypris-stage' through which the larva passes after the Nauplius-stage and directly before attachment. Balfour, however, in his treatise on *Comparative Embryology*, 1880, p. 424, emphasizes the presence of paired, compound eyes as well as the large bivalve shell, and has urged their "independent derivation from some early bivalve Phyllopod form."

It has further been recognized that a reduction in the number of the compartments (wall plates) or lateralia has taken place, probably by coalescence. The typical Balanus has four lateralia, two on each side; besides these the rostrum and carina, or six compartments in all. But the most generalized living genus Catophragmus has eight compartments, or three lateralia on each side. Paleontologists know in the Devonian fauna Protobalanus hamiltonensis Whitfield, an acorn barnacle with 12 compartments or 5 lateralia on each side

Investigations of the Utica and Lorraine faunas of the Upper Ordovician have recently brought to light a new form of acorn barnacle, which like Protobalanus, has five lateralia on each side, but differs in the form of these lateralia in such a way as to shed a most important light on the problem of the origin of the barnacles. In Protobalanus the five lateralia, which are all acutely triangular plates, point uniformly upward or inward towards the mouth. In the new form, which will be described as a species of the new genus Eobalanus, these plates are arranged as shown in the diagram, the four outer lateralia as in Protobalanus, while the middle one is inverted, forming a sort of keystone in the series. The second and fourth are furthermore somewhat truncated at the apex.

The effect of this peculiar shape of the lateralia is that, if they could be matched together like the parts of a picture puzzle, they would give a perfect, snugly-fitting carapace, as shown in diagram V. This carapace is bivalved as in phyllopods, with the rostrum and carina of the barnacle corresponding to the rostral plate of the crustacean in front and the 'dorsal plate' behind, exactly as in the Devonian genera Mesothyris and Rhinocaris.

We have then to picture the derivation of an Eobalanus as from a Rhinocaris-like phyllopod as illustrated in the set of diagrams. The first diagram


I
II
III
IV
V
n
d.pl
dorsal margin
v.m.
d.m
d
c
RHINOCARIS
I–V. DEVELOPMENTAL STAGES.
EOBALANUS
PROTOBALANUS
CATOPHRAGMUS
BALANUS

shows the carapace of the crustacean just before attachment with the head portion and the dorsal side downward—a rather natural position for phyllopods, which, like Apus, are wont to swim on their backs, while foraging along the bottom.

The head and back being thus protected by attachment, but the ventral side open to attack, the next step will be the separation of the carapace valves along the hinge line and their movement upward towards the ventral side; and likewise the rostral and dorsal plates will have to move upward to fit in again between the valves (stage II of diagrams). Following this was the breaking up of the valves into the lateralia, owing to stresses exerted at one or other end, possibly the anterior one where the originally chitinous and somewhat flexible valve was attached. Here also, our material affords a clue to the mode of procedure. A very early growth stage of Eobalanus shows four radially arranged, subequal, oval plates, the two lateral ones of which show a suture along which a smaller part is being split off. It is thus to be inferred that the compartments were formed by successive splitting off of plates from the original valve, each fissure producing a new pair of lateralia. In this way the peculiar interlocking arrangement of the compartments in Eobalanus would finally have come about and each valve of the carapace have been divided up without leaving a useless remainder.

The scuta and terga which form the valvular carapace or operculum of the upper aperture of the later Balanidae and Lepadidae and which are of great taxonomic importance, have not been found in Eobalanus and Protobalanus, and in our view did not exist then, but are a later development to close in more completely the ventral side. They are not fundamental structures.

POSSIBLE DERIVATION OF THE LEPADID BARNACLES FROM THE PHYLLOPODS

By John M. Clarke

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Communicated, October 29, 1918.

Mr. Ruedemann's discovery of an elemental balanid and his constructive deduction therefrom of the origin of the acorn barnacles, sets this form of symbiotic degeneration back to an historic stage, where its phylogeny is indicated in its own structure. The degeneration is already complete and hence implies a long time for the acquirement of such adaptation, but it is also so simple as to indicate its procedure. If Eobalanus intimates the rise of the Balanidae through the decline and dependence of the Phyllopods, it is opportune to regard the evidence bearing on the phylogeny of the other great division of the barnacles, the Lepadidae or Goose Barnacles.

There is a long lapse in the time record of this line of development for we have no present knowledge of the lepad barnacles, in the marine interval between the Jura and the Devonian. Certain rare fossils known as Turrilepas and Strobilepis have been found in the rocks of the Devonian, Silurian and Ordovician; Strobilepis is a singular genus constructed of four vertical ranges of plates, two rows broadly triangular and the other two narrow and spiniform, and the fact that this Devonian genus is known in but a single specimen prevents us from going far in utilizing it in this connection, but its structure, a scaly elongated body ending in a single subcircular plate from which the vertical ranges diverge, indicates that this plate is terminal at the free end of the animal; in other words, a caudal plate. In my previous discussions of this genus I have placed Strobilepis and Turrilepas together under the family Turrilepadidae, Turrilepas being the older in time and date of description and having similar structure except that the vertical ranges are from four to six, the scales of each range being more or less interlocked with those adjoining. This fact and the absence, so far as known, of a terminal or caudal plate, has led some students to regard Turrilepas as the scaly stalk of a lepad rather than the capitulum. However this may prove, I think we may be obliged to conceive that there is a less close relation between these two genera than their gross structures indicates.

In the Silurian and Ordovician we have the genus Lepidocoleus now standing as the representative of the family Lepidocoleidae and in this the type of structure is much simpler than in the genera mentioned. Here is an elongate body consisting of but two vertical ranges of plates, which are as distinctly 'lateral' in a morphological sense as are the lateralia of the balanids. These two rows open back and front making two continuous lines of suture or dehiscence from the base of attachment to the summit, where there is a terminal axial plate. The lateral plates are subequal half-rings or bands and the Lepidocoleus was attached to the surface on which it grew by its end and obviously by its head. My recorded observations on these structures in the *Palaeontology of New York*, VII, the *American Geologist*, *American Naturalist* and Eastman-Zittel's *Text Book of Palaeontology* are sufficient demonstrations of these relations.

Mr. Ruedemann's hypothesis of derivation predicates attachment of the ancestral phyllopod by its head and back; primarily by its head, secondarily and subsequently by its back. If we limit this fixation to attachment by the head alone leaving the rest of the body entirely free and hence subject to much more frequent and pronounced lateral stresses resulting from movements, by waters or otherwise, from side to side, we call into play only such stresses as reasonably seem to have been effective in the development of the Phyllocardia into Eobalanus.

The arguments and the causes are of the same category as those which my associate has employed. It is, therefore, a matter of special and confirmatory significance that these Lepidocoleus forms appear in the Ordovician; that is

to say that so far as our present knowledge extends the metamorphoses of the Phyllopods into the two great branches of the barnacles were essentially contemporaneous.

REFRACTIVE INDEX AND SOLUBILITIES OF THE NITRATES OF LEAD ISOTOPES

By Theodore W. Richards and Walter C. Schumb[1]

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Communicated October 31, 1918

The refractive index of the nitrate of pure common lead was compared very carefully with that of the nitrate of uraniolead prepared from the Australian material already mentioned in previous reports. The two samples of nitrates were separately recrystallized with care, and finely developed crystals were measured in the Abbé-Zeiss total-reflecting crystal refractometer. A solution of sulphur in methylene iodide having a refractive index of 1.79 was used as the contact liquid, and very careful measurements were made of many crystals in varying positions. The refractometer was standardized by means of a polished glass prism possessing an exactly known refractive index which could be verified by the method of minimum deviation. The refractive index of common lead nitrate at 20° was found to be 1.7815, and that of the uraniolead nitrate was found to be 1.7814—each value being a mean of many concordant determinations. Thus the difference in atomic weight shown by the two specimens of lead (the atomic weights are respectively 207.20 and 206.41) has no appreciable effect on the refractive index of the salt—a highly interesting and newly discovered fact.

The two specimens of lead nitrate which had been purified (crystals of which had been used in the preceding investigation) were further investigated with great care as to solubility, using a method recently described,[2] with small but convenient improvements. Greater difficulty was found in obtaining an exactly saturated solution than was the case with sodium sulphate, at least twenty-four hours at perfectly constant temperature being needed in order to obtain constant results. The weighed portions of solution saturated at 25.02° were evaporated with excess of sulphuric acid and the sulphate was gently heated at 350° until constant in weight. Four such determinations with ordinary lead nitrate gave values from 37.33 to 37.36 (average 37.342) grams of nitrate in 100 grams of solution, and nine determinations with uraniolead nitrate gave values from 37.26 to 37.30 (average 37.280) grams of nitrate in 100 grams of solution. These results are precisely proportional (within the limit of error of experiment) to the different molecular weights of the two samples of nitrate. Expressed in other terms, the molal solubilities of the two samples per thousand grams of water are respectively 1.7993 for

common lead nitrate and 1.7991 for uraniolead nitrate. The outcome of this work, then, by finding no appreciable difference in the molal solubility of the different samples of lead nitrate containing isotopes of widely different atomic weights, confirms earlier work upon other properties of these interesting substances. Evidently weight (or mass) is the prime distinguishing feature of the two kinds of lead here studied, as it was in other cases. This work and that described in the preceding section thus afford further support for the hypothesis due to Russell, Fleck, Soddy and Fajans.

[1] This paper and the two following are taken from an abbreviated version of a report to the Carnegie Institution of Washington (which generously subsidized the investigations) presented in August, 1918.

[2] Richards and Yngve, *J. Amer. Chem. Soc., Easton, Pa.*, **40**, 1918, (164).

THE PURIFICATION BY SUBLIMATION AND THE ANALYSIS OF GALLIUM CHLORIDE

By Theodore W. Richards, W. M. Craig, and J. Sameshima

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Communicated, October 31, 1918

A new method for the purification of gallium salts was worked out in some detail. This rests upon the convenient fact that gallium trichloride sublimes and distils at a low temperature, whereas the other chlorides likely to be associated with it are much less volatile. The method rested, therefore, upon fractional distillation and sublimation, at first in a stream of chlorine and afterwards in a vacuum, of impure gallium chloride.[1] The apparatus was a complex affair, in which gallium could be first burned in pure dry chlorine and then subjected to distillation either first in pure chlorine, then in nitrogen, and finally in a vacuum, the whole apparatus being fused together without rubber connections and scrupulously dried. In order to avoid the use even of ground joints (with their attendant alternative danger of leakage or contamination from lubricant) the gas connections were opened by means of sealed magnetic hammers acting on enclosed capillaries, and closed by fusion of the glass connections. The gallium was provided through the great kindness of Mr. F. G. McCutcheon of the Bartlesville Zinc Company, Blackwell, Oklahoma, to whom grateful thanks are due. Three successive distillations of the trichloride of gallium were made in chlorine at 220° to 230°C., three more at about 175° (the melting point of gallium dichloride), three in nitrogen at 90° to 110°, and five sublimations in vacuo at 65° to 80°—fourteen in all. Distillation in nitrogen or in vacuo is needful to eliminate dissolved chlorine. The resulting product showed no trace of any other substance in its spark spectrum when examined with great care in a Hilger wave length spectrometer. Although this study did not reach a final stage, and much more

remains to be done in order that perfect certainty may be attained, nevertheless the outcome must be regarded as promising in pointing toward an adequate and convenient method of separating gallium from other metals.

Three fractional samples of the chloride discussed in the previous section were analyzed, using the usual methods employed in Harvard University in order to make a preliminary determination of the atomic weight. The samples were small and for various reasons the results cannot be considered as anything more than preliminary, but the outcome is, nevertheless, worth recounting. In the last and best determination 0.43947 gram of gallium chloride (weighed in vacuo in a sealed glass tube) yielded 1.07087 grams of silver chloride having required 0.80587 gram of silver for complete precipitation. The atomic weight of gallium computed from these two sets of data are respectively 70.09 and 70.11—concordant results indicating a value somewhat higher than that usually accepted for gallium, but near enough to show that the chloride was at least not far from being pure, and that the whole proceeding is capable, when employed with larger quantities of material and with the experience already gained, of affording an accurate evaluation of this atomic weight. Of course such meagre data as those thus far secured furnish no worthy evidence concerning it; they are as merely preliminary as the data of Lecoq de Boisbandrau. At the conclusion of the war it is hoped that the joint investigation (which was stopped by the departure of W. M. Craig into War Service) may be continued and completed.

[1] The principle of this method has since been published by Dennis and Bridgman, although the details of their treatment differed from ours. Their work was entirely independent of ours (which was brought to a close in March, 1918) and was entirely unknown to us. *J. Amer. Chem. Soc., Easton, Pa.*, **40**, 1918, (1540).

THE PURIFICATION OF GALLIUM BY ELECTROLYSIS, AND THE COMPRESSIBILITY AND DENSITY OF GALLIUM

By Theodore W. Richards and Sylvester Boyer

Wolcott Gibbs Memorial Laboratory, Harvard University

Communicated, October 31, 1918

The method of separating gallium from indium by means of the different solubilities of the hydroxides in caustic alkali, recommended by various authorities, was tested without success. The separation was found to be so incomplete that several per cent of indium remained in the gallium, at least under the conditions used in our work, and it seemed clear that this difference in solubility is not enough to effect a complete separation. Much more promising results were obtained by the electrolytic method. Gallium occupies a place in the electrolytic series between indium and zinc. It is far less easy to deposit than indium, but, on the other hand, much more easy to deposit than zinc. By carefully regulating the hydrogen-ion concentration

and current density it was possible to deposit practically all of the indium with only a little gallium; and thereafter most of the gallium could be separated in a slightly acid solution without the appearance of an important amount of zinc. Gallium obtained in this way from material which had previously been purified by the hydroxide method, melted at a temperature as high as 30.8°, a higher melting point (indicating a purer substance) than is recorded anywhere in the literature. The metal obtained by the hydroxide process, without electrolysis, melted at a temperature as low as 26.9°. Time has as yet been lacking for making complete spectroscopic and other tests of this material in order to confirm its complete purity, but enough has been done to show that this method is a very satisfactory and convenient one. Because of its obvious advantages it must have been employed before by others, but no mention has as yet been found of it.[1]

Having thus prepared gallium of substantial purity, we proceeded to determine its compressibility, both in the solid and in the liquid condition. This was an interesting problem since comparatively few substances have been measured in both states. However, gallium has the remarkable and rare property of occupying more volume in the solid than in the liquid condition. The determination of the compressibility was desirable in order to add to the long list of elements already determined at Harvard. The apparatus and principle of the method was essentially similar to that employed in other cases, but a new difficulty was encountered. As in the case of other metals, the gallium could not, of course, be allowed to come in contact with the mercury in the piezometer, but on the other hand, it could not be conveniently solidified in any tube under such an inert liquid as toluene without bursting the tube. After many more or less satisfactory devices had been tried, the best results were obtained by solidifying gallium in the first place, and then placing a cylinder of the solidified metal in a slightly larger short test tube, just fitting it, and capping this with another similar slightly larger test tube under the inert liquid. Twenty-three grams of pure gallium were used in this work, and the compressibility was found to be 2.09×10^{-6}, placing gallium precisely on the curve joining the other compressibilities in the graph representing the periodic relation of this property to atomic weight. The compressibility of gallium containing several per cent of indium as obtained by the hydroxide method was found to be somewhat less (1.97×10^{-6}). Liquid gallium was determined not only in this apparatus but also in one similar to that used for caesium (Publication of the Carnegie Institution of Washington, No. 76, p. 20). The liquid was thus found to have a compressibility of 3.97×10^{-6}, a value almost exactly identical with that for mercury, and nearly twice as great as that of solid gallium, although its volume is less. The determination was made at 30°. This confirms the universal experience that solids have compressibilities distinctly less than the same substances as liquids, entirely irrespective of the volumes which they occupy. The most marked case of this kind thus far observed is that of ice.[2]

The densities also of solid and liquid gallium were determined,—data which have especial interest because the expansion of gallium on freezing has been attributed by some investigators to impurity. In the first place careful determinations were made by means of a pycnometer for solids[3] of the density of the impure material containing some indium in the solid and liquid condition, the values found being respectively 5.975 and 6.166. Subsequently when the purest material had been obtained, the determinations were repeated with equal care, giving values 5.885 and 6.081 respectively. Evidently indium had produced no essential effect upon the expansion on freezing and even if the more carefully prepared gallium was not absolutely pure, it is evident from the outcome, by extrapolation, that the purest gallium must still possess this unusual property.

[1] This method also has since been published by Dennis and Bridgman in their interesting article on Gallium.

[2] Richards and Speyers, *J. Amer. Chem. Soc., Easton, Pa.*, **36**, 1914, (491).

[3] Richards and Wadsworth, *Ibid.*, **38**, 1916, (222).

THE GROWTH-RATE OF SAMOAN CORAL REEFS

By Alfred G. Mayor

Department of Marine Biology, Carnegie Institution of Washington

Communicated October 30, 1918

In April, 1917, reef corals from Pago Pago Harbor, American Samoa, were measured, photographed, weighed, marked by numbered brass tags and replaced in favorable situations upon the reef-flats either by tying them with wire to iron stakes or imbedding their bases in concrete.

In July, 1918, these corals were again studied in order to ascertain their growth-rate, and as the specimens selected were of average size it was hoped that an approximate determination of the average growth-rate for each species might be determined. It was our object to calculate the weight of stony matter which coral heads of average size add to the reef per annum. In order to do this, the weight of the living coral was ascertained both in 1917 and in 1918. Then, in 1918, the coral was killed and its animal substance dissolved in KOH, after which the fresh water was largely abstracted by washing the skeleton in 90% ethyl alcohol; and finally the coral was dried in the sun, and then weighed.

This showed that the weight of the dried stony substance in various species of reef corals is on an average about 0.8 that of the same coral heads when alive. Various *Acropora* ranged from 0.7 to 0.9, while branched *Porites* were about 0.8, and large massive *Porites* slightly above 0.9.

Applying this correction, we find that on these Samoan reefs the gain in

weight of stony substance per year in various coral heads of average size appears to be as follows:

Acropora	19 ounces avoirdupois, or 539 grams per annum
Porites	8 ounces avoirdupois, or 227 grams per annum
Pocillopora	10 ounces avoirdupois, or 283 grams per annum
Pavona	12 ounces avoirdupois, or 340 grams per annum
Psammocora	3 ounces avoirdupois, or 85 grams per annum

Knowing the number of coral heads of these genera upon a reef-flat, we have a means for ascertaining the weight of limestone added to the reef each year by the growth of coral upon its upper surface.

By counting the numbers of coral heads and species of corals on squares of 24 feet on the side (576 square feet), the squares being staked out from 50 to 100 feet apart from the shore to the seaward edge of the reef-flat, we are led to the following conclusions:

On the upper surface of the Aua reef-flat between Breaker Point, Pago Pago Harbor, and the southern end of Aua Village, the area of the reef being 2,550,000 square feet, the number of corals are approximately as follows:

There are about 502,200 heads of *Porites* growing over 72% of the area of the upper surface of the reef-flat, and contributing (due to their growth) per annum 251,000 pounds of limestone.

347,500 *Acroporas* distributed over 56% of the reef-flat contribute annually 500,400 pounds of limestone.

57,600 heads of *Pocillopora* scattered over the entire reef-flat contribute 31,700 pounds of limestone.

55,900 Psammocora distributed over 30% of the reef-flat contribute each year 11,000 pounds of limestone.

15,500 Pavona found over 35% of the reef-flat area contribute each year about 11,600 pounds of limestone.

Thus the growth of these corals appears to add about 805,000 pounds of limestone each year to the upper surface of the reef-flat and as these genera contribute 95% of the entire coral heads of the reef-flat, it is probable that about 840,000 pounds or 380,500 kilograms of limestone is added to the coral reef each year by the growth of the corals over its surface.

There are, however, certain obvious losses which may be approximately determined. Among these the wash of the breakers due to the prevailing trade wind drives a current of about 40 feet per minute over the surface of the reef-flat from Breaker Point, northward to the jagged northern edge of the reef-flat over which the drifted limestone sand spills into deep water.

In order to determine the annual loss of loose limestone sand lost to the reef-flat by being drifted off its northern edge, 6 barrels each 2 feet in diameter were weighted with volcanic rocks and sunk off the reef-flat close to the northern edge so that the water was about 1 foot deep over their open tops at lowest tide.

It was found that on an average each barrel caught 0.7 of a pound of limestone sand per day; the sand being dehydrated in alcohol and dried in the sun before being weighed.

Further tests showed that the barrels caught on an average only 12% of the sand which was carried in the current over their open tops from the edge of the reef-flat.

The northern edge of the reef-flat is about 1200 feet wide, but sand spills over its edge along only about 800 feet of this length, the 400 outermost feet of reef edge being subjected to the constant inward wash of the waves.

Using these data, it appears that about 100,000 pounds of sand are washed off from the reef-flat by currents each year.

There are 290,000 holothurians on the Aua reef-flat between Breaker Point and the edge of the reef off Aus Village; and as the acidity of their gastric cavities appears to be the same as that of the holothurians of Florida, each one, according to experiments made at Tortugas in 1917, might be expected to dissolve 10 pounds of sand per annum; or 2,900,000 pounds of sand may be destroyed annually over this reef-flat by solution due to holothurians.

Thus the corals appear to add annually about 840,000 pounds of limestone to the reef, but 3,000,000 pounds, or nearly 3½ times this weight of limestone appears to be removed annually by holothurians and by currents, and other factors such as boring algae, mollusca and fishes; the efficacy of which we have not been able to calculate, add still more to the destruction of limestone although their influence is in some measure offset by the growth of nullipore algae, and lithothamnion. Alcyonaria although a decided factor in some reefs are so rare as to be negligible over the Aua reef-flat.

In most respects this Aua reef is a typical average Pacific fringing reef and our data appear to explain the disappearance of the lithothamnion ridge over the shoreward parts of the reef-flat as the reef grows outward. Moreover, the reef-flat appears to be deepening at present although the average depth of water over it at low spring tide is less than one foot.

This does not mean that such a fringing reef must necessarily change into a barrier reef through waste and solution of limestone from its floor, for as the reef-flat deepens the currents must lessen, and a sandy or muddy bottom, while unsuited to the growth of coral, is also not so favorable for holothurians as are the small patches of limestone sand surrounded by dead and living coral such as characterizes the Aua reef-flat today.

Thus as the reef-flat deepens, the factors which degrade it probably diminish and a balance may be attained between the accession of limestone due to growth of corals and other organisms and its loss due to mechanical and organic causes.

It is interesting to see that although *Porites* heads are more numerous than *Acropora*, yet *Acropora*, due to its remarkable growth-rate, is the most important coral genus in building up the Pacific reefs.

These results account for the disappearance of the lithothamnion ridge as the reef grows outward. This ridge is formed only on the breaker-washed seaward edge of the reef and it projects somewhat above low tide level, but as the reef extends seaward the ridge disappears over the shoreward parts of the reef-flat.

The growth-rate of these Samoan corals is nearly twice as rapid as is that of similar genera in Florida and the Bahamas, the growth rate of Atlantic corals being well determined due to the exhaustive studies of Vaughan.

This is probably due to the fact that in the Atlantic the corals live chiefly on the outer edges of shallow limestone flats the muddy bottoms of which become churned up by the waves, and pelagic life is largely killed in the water over the flats. Thus in the Atlantic, the corals are well fed only on the incoming tide, very little reaching them from the water passing outward from the flats.

In the Pacific, on the other hand, the lagoons are generally deeper than in the Atlantic and there is but little limestone mud so that the corals receive food both from the rising and from the ebbing tide; and, as is well known, the growth-rate of coelenterates is a factor of their food supply.

The following table shows the average increase in dimensions of corals from Samoa, and from the Florida-Bahama region; the growth-rate of the Atlantic genera being taken from the report by T. W. Vaughan, 1915, *Year Book of the Carnegie Institution of Washington*, No. 14, pp. 227–228.

GENUS OF CORAL, AND LOCALITY	AVERAGE INCREASE IN DIAMETER	NUMBER OF RECORDS	AVERAGE INCREASE IN HEIGHT	NUMBER OF RECORDS
	mm.		mm.	
Acropora from Samoa	98	21	48	21
From the Atlantic according to Vaughan*	54	71	35	42
Branched Porites from Samoa	47	6	25	6
From the Atlantic according to Vaughan	26	207	19	106
Massive Porites from Samoa	35	9		
From the Atlantic according to Vaughan	13	120		

* Vaughan's estimate is based upon branching species such as *Acropora cervicornis; A. prolifera* and *A. palmata*. My records of somewhat similar species in Samoa show an average increase in width of 178 mm. and 79 mm. in height. Many of the Samoan *Acroporas* are low, encrusting or dome-shaped forms such as are not found in the Atlantic.

It will be observed that on the average the 21 Samoan *Acroporas* each gained 539 grams in weight per annum. This appears to be about 3 times as great as the annual increase in weight of *Acropora palmata*, of the Bahamas, for Vaughan 1915 *loc. cit.* p. 230 gives this as 173 grams per annum.

The final paper of which this is a preliminary abstract will be published by the Carnegie Institution of Washington.

THE DISTANCES OF SIX PLANETARY NEBULAE

By Adriaan van Maanen

Mount Wilson Solar Observatory, Carnegie Institution of Washington

Communicated by W. S. Adams, November 7, 1918

In a previous note to these Proceedings[1] the parallax was published for the planetary nebula N.G.C. 7662. Attention was called to the scarcity of material then existing for the distances of the nebulae in general. The work has since been taken up with the 60-inch reflector of the Mount Wilson Observatory (the equivalent focal length of 80 feet being used), and in all, the parallaxes of eight nebulae have now been determined; six of these are planetaries, while the other two are spirals; the full details for the latter have been published in *Mount Wilson Contributions*, No. 158.

The images of the central stars were even better adapted to accurate measurement in the case of the five other planetaries measured after N.G.C. 7662 than on the plates of this object; here the nebulous ring was close to the central star and of considerable density; in all others, however, the nebula is either so much fainter than the central star, as in N.G.C. 2392, 6804, 6905, and 7008, that it is hardly visible on the plates, or it is at such a distance from the central star, as in N.G.C. 6720, that the nebula is not likely to interfere with measuring the central images. For this reason the existence of a large systematic error in the parallaxes is very improbable; other conditions also favor the belief that any systematic error will be small. As all the fields are near the Milky Way we have an abundance of comparison stars close to the central stars; in no case was the distance greater than seven minutes of arc; the central stars have in all cases the appearance of normal stars and are measurable with great accuracy.

N.G.C. 2392 is relatively bright; on that account a rotating sector with an opening of 36 degrees was used in order to make the central star comparable in magnitude with the faint stars which are preferably to be used for comparable purposes.

In table 1 the observational material is collected for the fields of all six planetaries.

The central star of N.G.C. 6720 is so faint that exposures of 35 or 40 minutes might have been better; fortunately, for this nebula another reliable parallax determination is available—that by Newkirk, who has derived from 74 plates taken with the Crossley reflector of the Lick Observatory a parallax of $+0''.015 \pm 0''.007$.[2] In the following discussion the weighted mean, viz., $+0''.008$, has been used for the absolute parallax.

To derive a homogeneous system for the photographic magnitudes of the central stars, counts were made of the number of stars of equal and brighter magnitudes in as large an area as the plates would allow; then with the help

of Table IV of *Publications of the Astronomical Laboratory at Groningen*, No. 27, the apparent photographic magnitudes, m, were derived.

The values are given in the third column of table 2; by means of the formula $M = m + 5 + 5 \log \pi$, we can derive the absolute magnitudes M, which are given in the fourth column.

The mean absolute magnitude is +9.1 and the deviations from this mean are small; this may be due to a small dispersion or to the choice of objects; the material, however, is still insufficient to discern which of the two possibilities is the cause.

This faint absolute magnitude, +9.1, is noteworthy because the spectra of these objects consist in many cases mainly of bright lines, whereas, with the stars at large, bright-line spectra are usually associated with high luminosities;

TABLE 1

N. G. C.	EXPOSURE TIME	NUMBER EXPOSURES	NUMBER OF COMP. STARS	π REL.	P. E.
2392	15^m	18	8	+0".020	±0".003
6720	25	14	9	+0.002	0.005
6804	25	18	8	+0.020	0.003
6905	20	18	9	+0.013	0.002
7008	20	20	9	+0.014	0.004
7662	25	16	8	+0.021	±0.004

TABLE 2

N. G. C.	π ABS.	m	M
2392	+0".022	10.0	+ 6.7
6720	+0.008	14.7	+ 9.2
6804	+0.022	13.4	+10.1
6905	+0.015	14.5	+10.4
7008	+0.016	12.8	+ 8.8
7662	+0.023	12.9	+ 9.7

for the Wolf-Rayet stars for instance, whose spectra resemble those of the planetaries in many respects, we find a mean absolute magnitude not far from 0.[3] On the other hand, assuming the relation between luminosity and radial velocity found for the stars to apply to the planetary nebulae, the high radial velocities observed for these objects, about 29 km. per second,[4] are in good agreement with their low intrinsic brightness. Thus, for 13 K and M stars of mean absolute magnitude 10.0, Adams and Strömberg found a mean radial velocity of 30 km. per second.[5]

One class of stars, which seems to take an intermediate position, is that of the novae, whose spectra pass through the planetary spectrum towards that of the Wolf-Rayet stars. The parallax-material, which is extremely scarce as yet and includes only 3 novae, points to absolutely faint magnitudes, in the

mean +6.9, for these stars when at their minimum luster. The radial velocities, however, for the three cases in which they have been determined, are small, in the mean 10 km. per second; this would indicate high luminosities. It should not be forgotten, however, that the relation between luminosity and radial velocity is based on stars of the same spectral type and it is questionable if this relation may safely be applied to stars of all types, including planetaries and novae.

The appearance of the nebulosity around Nova Persei and especially the little nebulous ring, which was photographed by Ritchey[6] and Pease[7] in 1917, opens the way for speculations concerning a possible relation between novae and planetary nebulae. To arrive at conclusions, however, further observational data are necessary.

The size of the planetary nebulae can be deduced from the above mentioned parallaxes, by which the diameters measured in arc can be converted into astronomical units or into light-years; the results are given in table 3; for the diameters in this table the major axes have been used.

TABLE 3

N. G. C.	DIAMETER		
	Angular	In astronomical units	In light-years
2392	46″	2,100	0.03
6720	80	10,000	0.16
6804	32	1,450	0.02
6905	47	3,100	0.05
7008	95	5,900	0.09
7662	31	1,350	0.02

By comparing these values with the size of our solar system (the diameter of the orbit of Neptune is 60 astronomical units) it is clear that the planetary nebulae must be of enormous size.

[1] Maanen, A. van, these PROCEEDINGS, **3**, 1917, (133–136).

[2] Newkirk, B. L., *Lick Obs. Bul., Univ. Cal., Berkeley*, **9**, 1917, (100–107).

[3] Maanen, A. van, *Pub. Astron. Soc. Pacific, San Francisco*, **30**, 1918, (308).

[4] Campbell, W. W., and Moore, J. H., these PROCEEDINGS. **1**, 1915, (496–498).

[5] Ritchey, G. W., *Pub. Astron. Soc. Pac., San Francisco, Cal.*, **29**, 1917, (256).

[6] Adams, W. S., and Strömberg, G., *Mt. Wilson Contr.*, No. 131; *Astroph. J., Chicago*, **45**, 1917, (293–305).

[7] Pease, F. G., *Ibid.*, **29**, 1917, (256–257).

NATIONAL RESEARCH COUNCIL

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING, JULY 9, 1918, AT 9.40 A.M.

Present: Messrs. Bogert, Cross, Dunn, Johnston, Kellogg, Merriam, Millikan, Noyes, Pearce, Woodward, and by invitation, Mr. Edgar.

The minutes of the preceding meeting, April 30, 1918, having been circulated by mail, were considered and approved.

The Acting Chairman, Mr. Noyes, reviewed the activities of the Council since the last meeting of the Executive Board, April 30, 1918, stating that the President of the United States had issued an Executive Order defining the functions of the Council, that the Carnegie Corporation of New York had made an appropriation of $100,000 for the expenses of the divisions, and that the President of the United States had allotted, through the Council of National Defense $61,000 for the running expenses of the Council, including the Research Information Committee, for the period from July 1 to December 31, 1918. He stated further that the work of the Research Information Committee had been increasing steadily, and that the third office had been established in Rome. He also briefly described the plan for the endowment of research in chemistry and physics which had been submitted to the Rockefeller Foundation.

The National Research Council budget was presented, and Mr. Dunn

Moved: That the allotments in the budget as presented be approved. (*Adopted.*)

Moved: That there be presented at each monthly meeting of the Executive Board a *budget sheet* showing for comparison the following items: Funds Available for the year, Total Amounts allotted, Liabilities, Expenses, and Balances. (*Adopted.*)

Motion adopted at the meeting of the Interim Committee, July 3, 1918: That the Carnegie Institution of Washington be requested to allow Mr. John L. Wirt, its bursar, to advise the National Research Council in regard to an improved accounting system for the carrying on of its business and that the Secretary and Treasurer be asked to confer with Dr. R. S. Woodward and Mr. Wirt in regard to the matter.

Mr. Woodward, being present, offered the services of the accountant of the Carnegie Institution of Washington, Mr. John L. Wirt and his assistant, to look into the accounts of the National Research Council and to make suggestions as to improved methods of carrying them on. The offer was accepted.

The National Research Council accepted full membership in the Emergency Council on Education, and J. C. Merriam was elected representative of the Council. The membership fee of $100 to cover expenses was authorized.

The President of the National Academy of Sciences has appointed as members of the National Research Council the following men, upon the recommendation of the Interim Committee:

Brig.-General Marlborough Churchill, Military Intelligence Division, U.S.A.
Major-General Wm. L. Sibert, Director, Chemical Warfare Service, U. S. A.
Brig. General Clarence C. Williams, Acting Chief of Ordnance, U. S. A.
Comfort A. Adams, President, American Institute of Electrical Engineers.
Philip N. Moore, Past President, American Institute of Mining Engineers.
A. A. Stevenson, Past President, American Society for Testing Materials.
George S. Webster, American Society of Civil Engineers.

Generals Churchill, Sibert, and Williams automatically become members of the Military Division; Messrs. Adams, Moore, Stevenson, and Webster were elected members of the Engineering Division to represent the Societies as indicated.

Paul Brockett was elected Assistant Secretary of the National Research Council.

The franking privilege was extended to the Committee on Patents, the Camouflage Committee, and the Committee on Neurology and Psychiatry, for official correspondence.

Mr. Hale requested in a telegram that all persons holding office connected with the National Research Council should take the 'oath of office' and the Interim Committee has directed that this be done.

The appointment of the Committee on Nitrate Investigations was reported and it was decided to report to the Executive Board the official authorization of this Committee contained in the following letter:

April 16, 1918.

From: The Acting Chief of Ordnance.
To: Mr. Edward R. Stettinius, Second Assistant Secretary of War.
Subject: Plan for organizing nitrate investigations.

1. Under date of March 30 the National Research Council submitted to you a plan for organizing nitrate investigations. This plan was referred by you to the Ordnance Department and by direction of the acting chief of ordnance was the subject of conference between the officials of the Nitrate Division and Drs. Hale, Johnston, and Noyes of the National Research Council.

2. The following report is submitted as a joint recommendation:

It is our opinion that the best method of securing the desired coöperation is for the Secretary of War to request the National Research Council to designate two or more research men, who shall be appointed Consulting Chemists to the Ordnance Department, and who, together with the officer in charge of the Research Section of the Nitrate Division (now Lieutenant Colonel A. H. White), shall constitute a small executive committee whose duties shall be (a) to survey the researches now in progress, (b) to plan further investigation relating to nitrogen-fixation processes, (c) to arrange for the active prosecution of such investigations, and (d) to exercise close oversight over their progress; the actions taken by this committee and the allotment of funds recommended to it to be subject to the approval of the Chief of the Nitrate Division.

It has been arranged that, if this request be made, the Council will designate as Chairman of the Committee, Arthur A. Noyes, Chairman of the Nitrate Supply Committee appointed by the Secretary of War, and Director of the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology; and as second member of the Committee, John Johnston, Executive Secretary of the National Research Council and

Chairman of its Division of Chemistry and Chemical Technology, and Research Chemist of the American Zinc, Lead and Smelting Company. Both these men are resident in Washington and will devote a large part of their time to the work.

For the Nitrate Division

(Signed) J. W. JOYES,
Col. Ord. U. S. A.

For National Research Council

(Signed) GEORGE E. HALE,
Chairman,

(Signed) JOHN JOHNSTON,
Secretary,

(Signed) ARTHUR A. NOYES,
Chairman of Nitrate Committee.

I recommend that this joint report be approved:

(Signed) W. S. PEIRCE,
Brig. Gen. Ord. N. L. Acting Chief of Ordnance.

1st Ind.

Office of Second Assistant Secretary of War. To the Acting Chief of Ordnance.

1. Forwarded. Approved.

(Signed) EDW. R. STETTINIUS,
Second Assistant Secretary of War.

Division of General Relations.—The name of the Administrative Division was changed to Division of General Relations (including Foreign Relations, State Council Relations, Industrial Relations, and Relations with Educational Institutions). The Chairman gave a general account of its recent activities.

Committee on Relations with Educational Institutions.—The Chairman, Mr. Merriam, said that at the request of the Committee on Education and Special Training, the question of the reorganization of the courses in colleges and universities to meet war purposes had been considered, and that the Division of Geology and Geography had formulated plans for the reorganization of methods of presenting new courses or modifications of courses in the fields covered by that Division. It was

Moved: That the Council express an interest in the scheme which the Committee on Education and Special Training has in preparation and a willingness to assist the Committee in such ways as it may desire. (*Adopted.*)

Research Information Committee.—S. L. G. Knox was named Scientific Attaché of the American Embassy at Rome, and Edgar Buckingham, of the Bureau of Standards, was elected Technical Assistant to the Scientific Attaché at Rome.

Mr. Noyes brought up for consideration the work of the Research Information Committee and presented the following order from the War Department in regard to the part that the Army would take in cooperating with the National Research Council in the securing and distributing of information:

WAR DEPARTMENT,
THE ADJUTANT GENERAL'S OFFICE,
WASHINGTON

July 2, 1918

From: The Adjutant General of the Army.
To: The National Research Council, Washington, D. C.
Subject: Information Section, Ordnance Department, and Research Information Committee.

1. The Secretary of War directs that you be informed as follows:

2. The Research Information Committee was formed to establish machinery by means of which the General Staff of the Army and Navy, the scientific organizations in the United States who are working on problems connected with war production and invention, and the various committees of the Council of National Defense charged with work of this nature, may be put in touch with the developments and experimental work being carried on, not only in this country, but in Europe, and kept mutually informed of the state of development of work of this nature.

3. In pursuance of the order of the Secretary of War, establishing this Committee and in order effectively to do this work, it is vitally necessary that the utmost of cordial cooperation be shown by each of the bureaus and committees in question with the Research Information Committee. To secure this the following is directed:

(a) All military Bureaus requiring scientific and technical information are given official status on the Research Information Committee in Washington, D. C.

(b) Representatives of Military Bureaus or of research committees collecting information abroad will be instructed, by their chiefs, to put themselves into direct relationship with the joint committees of the Research Information Committee sitting in Paris or London or later in Rome, in order that information be at once dispatched to the Research Information Committee at Washington, D. C. All communications of scientific investigations or research shall be routed through these channels, even though other channels are employed at the same time.

(c) Official means of intercommunication, such as memorandums, bulletins and the like, between Bureaus of the Army and Committees for research shall be developed to such a degree of efficiency by the Research Information Committee that the distribution of information shall be practically automatic.

(d) Before sending officers or civilians abroad for investigation work, all Army Bureaus or civilian research committees shall get in touch with the Research Information Committee at Washington, D. C. for information and guidance.

(e) The present method of routing information memoranda for file and distribution through the Military Intelligence Branch will not be discontinued.

(f) You will immediately notify this office and the Research Information Committee of the name of the officer who shall represent your Bureau before the Research Information Committee.

By order of the Secretary of War:

(Signed) PAUL GIDDINGS,
Adjutant General.

Moved: That a medical representative be appointed for the Paris office of the Research Information Committee, provided the expenses can be met from the Medical Division or from outside sources. (*Adopted.*)

Engineering Division.—Reference was made to the affiliation with engineering societies and the forming of an advisory board composed of representatives of the chief engineering societies. Ambrose Swasey and John R. Freeman, were elected members of the Division, and W. J. Lester was elected

Vice-Chairman. The following men were elected to membership in the Engineering Division to represent the Societies indicated:

Comfort A. Adams, President, to represent the American Institute of Electrical Engineers.

Philip N. Moore, Past President, to represent the American Institute of Mining Engineers.

A. A. Stevenson, Past President, to represent the American Society for Testing Materials.

George S. Webster, to represent the American Society of Civil Engineers.

Section on Mechanical Engineering.—The resignation of S. L. G. Knox as Chairman of this Section was accepted with regret, and W. J. Lester was elected Chairman in his place.

Section on Tanks.—A. J. Mason was elected Chairman of this Section.

Section on Metallurgy.—W. P. Barba, G. W. Sargent of the Ordnance Department, and J. E. Johnson, Jr. have been added to this Section.

Section on Electrical Engineering.—C. A. Adams was elected Chairman of this Section.

Engineering Committee.—Mr. Dunn asked if the old Engineering Committee had been in existence or was in existence since War Organization was adopted on March 9, 1918. After discussion it was *Moved:* That notices be sent to the members of the former Engineering Committee by the former Chairman, advising them of the new war organization under plans of March 9, 1918, and inviting their continued cooperation to such an extent as the time during which they can be present in Washington will permit. *Adopted.*

Mr. Dunn stated that while he was Chairman of the Engineering Committee, he had asked the J. G. White Engineering Corporation of New York, to prepare for the National Research Council an elaborate paper on "Clean Coal vs. Dirty Coal," and that a well-illustrated pamphlet had been prepared and printed; of which about 100 copies had been distributed. The plates having been unfortunately destroyed, he now asked authority to reprint the pamphlet, and it was:

Moved: That the J. G. White Engineering Corporation be given permission to reprint the Clean Coal Report of the Engineering Committee of the National Research Council, provided credit be given to the National Research Council for the report. (*Adopted.*)

Division of Chemistry and Chemical Technology.—Since the last report the Executive Committee of the Division has been constituted, as follows:

*John Johnston, Chairman.

Samuel Avery, Vice-Chairman.

Graham Edgar, A. A. Noyes, E. W. Washburn, National Research Council.

W. D. Bancroft, E. P. Kohler, A. B. Lamb, American University Experiment Station.

*C. L. Alsberg, Bureau of Chemistry.

C. L. Parsons, Bureau of Mines.

W. F. Hillebrand, Bureau of Standards.
M. T. Bogert, Chemical Warfare Service, N. A.
H. D. Gibbs, U. S. Signal Corps.
S. A. Tucker, War Industries Board.
*Willis R. Whitney, Naval Consulting Board.

* Nominated to membership by American Chemical Society.

The Division is holding regular meetings lasting for about half an hour on Monday, Wednesday and Friday morning of each week, at which matters of interest are brought up as they arise.

The Division organized a conference on the whole question of explosives, which was attended by representatives of the Army, the Navy, certain civil bureaus of the Government, and by representatives of the large explosives firms. As a result of this conference, it was arranged that an active committee should be appointed to take charge of this whole matter, and accordingly a Committee on Explosives Investigations is being organized. The constitution of this Committee is:

Charles E. Munroe, Chairman.
W. C. Spruance, Jr., Lieutenant Colonel, Ordnance Department.
L. L. Summers, War Industries Board.
T. S. Wilkinson Lieutenant Commander, U. S. N.

E. W. Washburn of the University of Illinois was elected a member of the Chemistry Division; he is especially interested in the question of allocating research problems to men still at the universities and has already made substantial progress in this matter.

Committee on Gases Used in Warfare.—It seemed to be the opinion of the meeting that this Committee may now be discontinued since the present status of this whole work and its absorption by the War Department leaves little or nothing for the Committee to do; but it was thought that no action should be taken in this direction until Mr. Manning's recommendation should be received.

Moved: That the National Research Council express to the Committee on Gases Used in Warfare its high appreciation of the work initiated by that Committee and ably carried out through the efforts of its Chairman, Mr. Van H. Manning, Director of the Bureau of Mines; and thank the Committee for their work. (*Adopted.*)

Division of Geology and Geography.—The Chairman of the Division, Mr. Merriam, reported that Isaiah Bowman, Director of the American Geographic Society, had been elected a member of the Executive Committee, and J. E. Spurr, a member of the Division. The following two books have been recommended for inclusion in the official list of military books:

W. M. Davis, Handbook of Northern France.
D. W. Johnson, Topography and Strategy in the War.

The following subjects have been considered and acted upon by the Division:

Course of map making at Columbia University.
Lectures on Geography of Northern France.
Card system for personnel in geology and geography available in this country for special kinds of service.
Assistance in selection of camp sites.
Road material report (deposited in U. S. Geological Survey).
Army map instruction in relation to armies in the field.
Needs of war service to geologists.
Instruction in training camps on the subject of Geology and Geography.
Exchange of information bearing on geologic and geographic work.
Coöperation with Committee on Scientific Research of California.
Resources of clear quartz crystals available in this country.
Instruction in geology and geography in educational institutions (in charge of a special committee as follows: C. K. Leith, Chairman, R. A. F. Penrose, Lawrence Martin, Isaiah Bowman, E. B. Matthews.)

Division of Medicine and Related Sciences.—The Chairman of this Division, Mr. Pearce, after reviewing the activities of the Executive Committee, reported progress on the following problems in research work:

The toxicity of Preserved Foods.
Protectors for the ear.
Production of acetone by the fermentation of starch.
Special researches on antiseptics and insecticides.
Louse investigations.
Study of special and rare sugars.
Influence of high explosives in causing shock.
Studies of peripheral nerve injury and repair.
Experimental study of empyema due to streptococcus.
Studies of Anaerobic bacteria.
Studies of hemolytic streptococci occurring in cheese.
Investigation of lung motor.
Study of 13,000 records of soldiers discharged from service on account of nervous or mental trouble.
Discovery of metal or other substitute for petri dish.
Study of Hemostatics.
Investigation of edema among infants
Problems of munition workers.
Critical study of Dreyer's method of testing agglutine of typhoid.
Under the *Sub-Committee on Physiology:*
Study of the Physiology of Shock.
Respiratory Regulation of the CO_2 Capacity of the Blood.
Under the *Sub-Committee on Physiological Chemistry:*
A study of the availability of velvet beans.
The use of malt sugar as a substitute for cane sugar.
The substitution for acetone for various therapeutic products.

Committee on Intoxications among Munition Workers.—The present membership of this Committee is as follows:

H. Gideon Wells, University of Chicago, Chairman.
Alice Hamilton, Bureau of Labor Statistics.
David L. Edsall, Massachusetts General Hospital, Boston, Mass.
A. D. Reilley, Captain, Ordnance Department.

Committee on the Physiology of Shock.—Elected to membership on this Committee:

G. N. Stewart, of Western Reserve University.

Committee on Neurology and Psychiatry.—The name of this Committee was changed to "Committee on Neurology and Psychiatry;" and E. E. Southard of the State Psychopathic Hospital of Massachusetts was appointed Acting Chairman with authority to reorganize the Committee; the present Chairman, Stewart Paton, now in active military service, remaining nominally as Chairman.

Committee on Toxicity of Preserved Foods.—The following names were approved as members of this Committee:

J. J. Abel, Professor of Pharmacology, Johns Hopkins Medical School, Chairman.

M. J. Rosenau, Professor of Preventive Medicine, Harvard Medical School.

Sub-Committee on the Study of Fatigue in Relation to Industrial Pursuits.—Upon recommendation of the Chairman, F. S. Lee, the membership of this Committee was completed by adding the members of the Committee on Industrial Fatigue of the Division of Labor of the Council of National Defense, the Committee as enlarged being as follows:

Frederic S. Lee, Professor of Physiology, Columbia University, Chairman.

Thomas Darlington, Secretary Welfare Committee, American Iron and Steel Institute.

Robert E. Chaddock, Associate Professor of Statistics, Columbia University.

Raymond Dodge, Professor of Psychology, Wesleyan University.

David L. Edsall, Professor of Clinical Medicine, Harvard Medical School.

P. Sargent Florence, Organizing Secretary of the Committee of the British Association for the Advancement of Science, appointed to investigate Fatigue from the Economic Standpoint.

Josephine Goldmark, Publication Secretary, National Consumers' League.

Ernest G. Martin, Professor of Physiology, Leland Stanford University.

J. W. Schereschewsky, Officer in Charge of Field Investigations in Occupational Diseases and Industrial Hygiene, Public Health Service.

Ernest L. Scott, Associate in Physiology, Columbia University, Captain Sanitary Corps, U. S. A.

A. W. Ryan.

Division of Agriculture, etc.—The Chairman of the Division, Mr. Kellogg, reported that A. F. Woods, of Maryland State Agricultural College, has been elected Chairman of the Committee on Agriculture, and Vice Chairman of the Division; and that the following problems were under consideration: Tropical Hardwoods, Fish Preserving, Rodent Pests.

Special Committee on Sisal and Sisal Substitution.—This committee has been formed for the consideration of the problem of sisal and sisal substitution for use as binder twine, with E. M. East, Bussey Institution, as Chairman.

Special Committee on Fertilizers.—The following members have been appointed on this Committee and a plan for publicity work to educate the people on the subject has been formulated:

A. F. Woods, Chairman, E. W. Allen, F. J. Alway, S. Avery, K. F. Kellerman, W. G. Lipman, B. E. Livingston.

Moved: That the Special Committee on Fertilizers be allotted the sum of $1,000 or such part thereof as may be necessary to meet the general expenses of that Committee, from the allotment for the Division of Agriculture. (*Adopted.*)

Moved: That the Special Committee to undertake a determination of Physiological Salt Requirements of certain Cultivated Plants be allotted an appropriation of $2250 or such part thereof as may be necessary for the general expenses of that Committee, from the allotment of the Division of Agriculture. (*Adopted.*)

Moved: That the Special Committee on Problems of Protein Metabolism in Animal Feeding be allotted $500 for current expenses from the allotment of the Division of Agriculture. (*Adopted.*)

Mr. Woodward *Moved:* That the above acts of the Interim Committee be approved, ratified and confirmed. (*Adopted.*)

The Board adjourned at 12.45 a.m.

PAUL BROCKETT, *Assistant Secretary.*

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING, AUGUST 13, 1918, AT 9.35 A.M.

Present: Messrs. Dunn, Mendenhall, Merriam, Noyes, Southard, Washburn, Welch, Woods, Woodward, and Yerkes.

The Acting Chairman reviewed the work of the Research Council since the last meeting; a general statement of the activities of some of the Divisions is appended.

The holding of a joint meeting of the Executive Board with the Council of the National Academy on Monday, September 9, to consider matters to be presented to the conference of Academies in London on October 9, was approved.

Committee on Reconstruction Problems.—Mr. Merriam presented a report from the special committee brought together to consider plans for reconstruction work after the war.

Moved: That the following recommendations of the Committee be approved:

That a committee be constituted on Reconstruction Problems, to be appointed by the Acting Chairman.

That this committee be empowered to increase its membership by associating with itself experts in each line investigated and to coöperate with other organizations engaged in reconstruction work.

That an appropriation of $5,000 be made to cover necessary clerical and traveling expenses, procuring of documents, and reports, provided funds are available.

That the committee be instructed to map out the whole field of reconstruction, and ascertain what agencies are now working in each portion of the field.

That the committee make plans for research into important reconstruction problems, within the scope of the activities of the National Research Council not now being covered and to indicate the agencies which should undertake this work. (*Adopted.*)

The Chairman read the following letter of July 25, 1918, from Ralph Barton Perry, Executive Secretary of the Committee on Education and Special Training of the War Department to the Acting Chairman, Mr. Noyes:

I beg to submit the following vote passed at a meeting of the Executive Committee on College Training, held Tuesday, July 23, 1918:

"*Voted* to invite the National Research Council to form a committee for the purpose of reviewing cases of research men who may be candidates for the Enlisted Reserve Corps."

Moved: That the Chairman of the National Research Council be authorized to appoint a committee of five, of which the Chairman shall be a member, to recommend to the Committee on Education and Special Training men of draft age engaged in research of such importance that it seems desirable to have them assigned to scientific work rather than to purely military service. (*Adopted.*)

The Chairman appointed the following committee: J. C. Merriam, Chairman, R. A. Millikan, R. M. Pearce, Vernon Kellogg, A. A. Noyes.

Section on Relations with Educational Institutions and State Committees:—

Resolved: That the administration of the Section on Relations with Educational Institutions and State Committees be extended by arranging the work for the United States so that it will be related to four districts representing approximately the North Atlantic, Southern, North Central, and Pacific Coast-Rocky Mountain regions, and that under the direction of this Section a representative resident in each of these regions be appointed to confer with Chairmen of local committees, to promote the interests of research, and to care for the relations between the Research Council and the local committees. (*Adopted.*)

Division of Chemistry and Chemical Technology:—At the preceding meeting of the Executive Board the matter of the discontinuance of the Committee on Gases Used in Warfare was taken up, but it was decided to defer definite action until a recommendation from Mr. Van H. Manning, Chairman of the Committee, should be received. Mr. Manning wrote recommending that this Committee be discontinued, and it was

Moved: That in accordance with the recommendation of Mr. Manning, the Committee on Gases Used in Warfare be dissolved. (*Adopted.*)

The meeting adjourned at 11.45 a.m.

PAUL BROCKETT, *Assistant Secretary.*

General statements as to the recent activities of some of the Divisions are appended.

Division of General Relations.—Section on Relations with Educational Institutions and State Committees. The Section has secured and transmitted reports to the War Department Committee on Education and Special Training, on the

matter of instruction in scientific subjects with a view to making a recommendation as to the best organization of courses to meet emergency needs. These reports have been discussed with the members of the above Committee and they will be transmitted to the educational institutions with the recommendations of this Committee relating to the organization of instruction for the coming year. The Division of Geology and Geography is working on the preparation of a text book and syllabus to follow the report transmitted and it will probably be desirable for other Divisions of the Council to prepare similar detailed reports on instruction for emergency work.

The Section has been receiving information from the research committees in educational institutions and now has sufficient data to enable it to prepare a preliminary report on the present state of emergency research in the universities and colleges of the country. It has also kept in close touch with the American Emergency Council on Education which is doing important work in bringing together the educational institutions of the country. Of special importance at the present time is the organization of a group of prominent educators to consider the reconstruction policy of this country, a question which involves the matter of research in educational institutions.

Division of Engineering.—Section on Mechanical Engineering. This Section has taken possession of the machine shop and laboratory of the Carnegie Institute of Technology at Pittsburgh for its work. It has about seven men now at work there and expects to increase their number to twenty or thirty very soon. The Section is preparing to develop several new types of light engines, and to experiment on the more efficient use of gaseous fuel.

Section on Metallurgy. This Section is arranging for the manufacture and ballistic testing of lots of several hundred each of helmets made from five types of steel, which in the preliminary tests have given the greatest promise. It has made encouraging tests with some new types of gun. In coöperation with the Bureau of Standards, Bureau of Mines and the Geophysical Laboratory it is making investigations looking towards the economy of manganese in ore-smelting and in steel-making, with the purpose of releasing vessels now used in bringing mangenese ore from abroad. It is arranging to coöperate with the Production Division of the Ordnance Department in standardizing the manufacture of fire-arms. In connection with the Section of Electrical Engineering and the Emergency Fleet Corporation it is seeking to improve the electric welding of ships.

Division of Chemistry and Chemical Technology.—Changes in the Executive Committee of the Division. Since the last report of the Division the following changes have occurred in the Executive Committee: Dr. Samuel Avery has resigned as Vice-Chairman and Dr. E. W. Washburn has been appointed to fill the vacancy. At the direction of Colonel Bogert, Majors Avery and Rogers of the Chemical Warfare Service have been assigned to represent this service at the meetings of the Executive Committee. Owing to the resignation of Pro-

fessor S. A. Tucker from the War Industries Board a vacancy has been created in the Executive Committee of the Division which has not yet been filled.

Activities of the Sub-Committees. The following sub-committees of the Division have been especially active: (1) The Committee on Synthetic Drugs; (2) The Committee on Ceramic Chemistry; (3) The Committee on Glue and Other Colloids.

The Committee on Synthetic Drugs has been in close coöperation with the Federal Trade Commission, has initiated several investigations dealing with the manufacture of special drugs, and has arranged to have a number of these drugs recently unobtainable manufactured by American firms.

The Committee on Ceramic Chemistry is engaged in the preparation of two manuscripts dealing respectively with (a) the formation of an organization for coöperative research in the subject of refractory materials, and (b) the formation of a similar organization for the investigation of the washing, blending, and preparation of clays. Under the auspices of this committee a conference was held in Pittsburgh in June, and an organization formed for undertaking a coöperative survey of the ceramic raw materials of the country. This cooperative survey has been inaugurated and is being carried out under the direction of the American Association of State Geologists.

The Committee on Glue and Other Colloids has taken up the question of the standardization of Government specifications for glue.

The Sub-Committee on the Chemistry of Soils and Fertilizers has been discharged and a new fertilizer committee organized under the Division of Agriculture, but with representatives from both divisions, has been constituted with the following personnel: Messrs. Allen, Alway, Avery, Kellerman, Lippman, Livingston, and Woods, Chairman.

University Research on War Problems. The work of collecting and assigning war problems to university laboratories for investigation is proceeding satisfactorily. The Vice-Chairman has established relations with the Chemical Warfare Service, the Surgeon General's Department, the War Industries' Board, the Nitrate Committee, the Explosives Committee, and the United States Signal Corps, for the purpose of securing such problems. Thus far, 25 problems have been formulated and 11 have been assigned.

The Training of Chemists for Government Service. At the request of the War Department's Committee on Education and Special Training the Vice-Chairman has undertaken to collect data concerning the numbers of chemists required for Government service, together with data concerning any special training which such chemists should have to fit them for Government work. On the basis of these data recommendations concerning any desirable modifications in or additions to collegiate courses in chemistry will be formulated and transmitted to the colleges and universities.

International Cooperation in the Publication of Chemical Abstracts. On the initiative of the Division a conference was held recently in Washington and plans were formulated for the presentation to the English Chemical Societies

of a scheme for international coöperation in the collection and publication of chemical abstracts.

Division of Geology and Geography.—The work of the Committee on Geologic Service in the field of military operations has been completed. The Secretary of War reports that the geologic service will be included in the work of the Engineer Corps, and General Black, Chief of Engineers, states that the Corps is taking up geologic work both in the United States and abroad. Appreciative reference is made to the work of our Division which seems to have served a good purpose. At the present time the geologic service of the Central Powers is greatly superior to that of America and our Allies and is very effectively employed; but there is no doubt that we shall soon surpass the German army in this field of endeavor.

The committee on suggestions as to inclusion of materials from geography and geology in the training courses for officers and men, after a carefully conducted examination of the field, has made its report to the War Department. This report is very favorably received and will be acted upon in the near future. Much credit for this work is due Dr. C. P. Berkey.

The committee on preparation of recommendations on the best organization of instruction in geology and geography has reported and this statement is in the hands of the Committee on Education and Special Training.

Division of Agriculture, Botany, Forestry, Zoology and Fisheries.—In the Agriculture Committee special consideration has been given the problem of fertilizers. This Committee has cooperated with the Fertilizer Committee of the Division of Chemistry. In accordance with the joint recommendation of the two Divisions, the fertilizer work has now been consolidated under the Committee on Agriculture with a Special Committee made up of representatives of the two Divisions. Plans are being formulated to bring about coöperation in some of the larger fertilizer questions facing the country. Representatives of the State Colleges of Montana, North and South Dakota, Minnesota, Wisconsin, Iowa, Nebraska and Kansas were asked to form a special organization coöperating with the National Research Council for the purpose of collaborating in the study of the fertilizer problems of that area with special reference to the most economical use of the large deposits of phosphate rock in Montana in connection with the utilization of the large quantities of sulphuric acid that will be available following the war. It is planned also to study the possible utilization of ammonia compounds which will be available as by-products of war industries. It is planned to develop similar coöperative organizations in the study of other fertilizer problems. A special sub-committee has been organized for certain research work in connection with potash substitutes.

A special Committee on Fibers is making a study of the fibers available for binder twine.

The work in Animal Nutrition is being continued in accordance with the project already approved. Plans for a conference of the collaborators of this project have been formulated and the Committee will meet for a special conference early this fall. The work is proceeding satisfactorily.

The Committee on Zoology has been cooperating with the Department of Agriculture in calling attention to the methods of destroying rats and mice to prevent their depredations on stored food products. Through the Council of National Defense an urgent appeal is being sent to all State Councils to utilize the valuable methods recommended by the Department of Agriculture to fight this pest.

The Division is cooperating with the Division of Geology and Geography in gathering information from various colleges in the country as to modifications of courses of instruction to meet war conditions.

MINUTES OF JOINT MEETING OF THE EXECUTIVE BOARD AND THE COUNCIL OF THE NATIONAL ACADEMY OF SCIENCES

AT THE NATIONAL RESEARCH COUNCIL BUILDING, SEPTEMBER 9, 1918 AT 9.50 A.M.

Present: Messrs. Abbott, Dunn, Gregory, Hale, Howe, Johnston, Kellogg, Lester, Manning, Mendenhall, Millikan, Noyes, Pearce, Pupin, Stratton, Yerkes, and by invitation Durand, Flexner, and Gunnell.

The minutes of the preceding meeting, and of the intervening meetings of the Interim Committee, having been circulated by mail, were approved.

In considering the request of Dr. Schuster of the Royal Society as to the utility of the International Catalog of Scientific Literature, Mr. L. C. Gunnell described the present organization of the International Catalog and the difficulties under which it has been operating since the war began.

Mr. Noyes *moved:* That, before continuing the publication of the International Catalog, full consideration be given to the practicability of securing coöperation and avoiding duplication in the whole field, including the preparation of indexes, bibliographies, and abstracts of scientific literature. (*Adopted.*)

Moved: That the Chairman of the Research Council, Mr. Hale, act as a member and Chairman of the Research Information Service. (*Adopted.*)

Moved: That in the absence of the Chairman, Mr. Noyes, Mr. Merriam act as Chairman of the Division of General Relations and Mr. Johnston as Chairman of the Committee on Nitrate Investigations. (*Adopted.*)

Moved: That a Budget Committee of three be appointed by the Chairman to take charge of the accounts of the National Research Council. (*Adopted.*)

The Chairman appointed the following Committee: John Johnston, Chairman, Whitman Cross, R. S. Woodward.

Mr. Hale *moved:* That a small local committee on submarine research work be appointed in California, with headquarters at Pasadena, with Professor Harris J. Ryan, of Stanford University, as Chairman. (*Adopted.*)

The Chairman, Mr. Hale, asked for a discussion of the plans suggested for consideration by the Inter-Allied Conference, to be held in London on October

9 at the request of the Royal Society of London, for the benefit of the delegates present at this meeting.

The meeting adjourned at 12 o'clock.

PAUL BROCKETT, *Assistant Secretary.*

There is appended hereto a brief statement of the activities of some of the Divisions of the National Research Council.

Division of Engineering.—The Section of Mechanical Engineering is carrying on its work in its Pittsburgh machine shop and has increased its personnel slightly. It is engaged on problems concerned with the development of a number of devices for the use of aircraft, of special balloons and parachutes, of mechanism for the control of trucks and tractors, and is undertaking a general investigation of fatigue of metals.

The work of the Section on Prime Movers on the special engine has been suspended for lack of funds; a special carburetor is being developed.

In the work of the Section on Metallurgy on manganese saving, cooperation has been established in the investigations which they will make jointly with the Bureau of Standards and the Bureau of Mines; and already ten of the thirteen important smelters of manganese ore and eleven out of the sixteen open hearth steel works approached, have promised to cooperate.

A committee is being formed to recommend the proper procedure in making and treating steel ingots for the better class of uses such as cannon, crank shafts, shells and armor. A second committee will take up the question of devising a pyrometer capable of measuring the temperature of the molten steel in open hearth and electric furnaces. Experimental work on the pressing of steel of various compositions into helmets has been begun.

Division of Physics, Mathematics, Astronomy and Geophysics.—A considerable fraction of the problems which are catalogued under the activities of the Physical Science Division of the National Research Council are associated with the work of the Science and Research Department of the Bureau of Aircraft Production. This work is at present carried on by about twenty officers and an equal number of civilian employees of scientific and technical qualifications, in addition to some hundred and twenty enlisted men. This does not include the 500 men who carry on in this country and abroad the work of the Meteorological Service of the Army, which is one of the sections of the Science and Research Department.

The work in this country is carried on at Washington, Langley Field, Baltimore, Pittsburgh, at a number of universities, and at several aviation fields. At Langley Field there is a laboratory which employs some thirty officers and men and keeps some ten airplanes continuously engaged on experimental work. At Washington there are some seventy enlisted men working at the Bureau of Standards under the direction of the officers of the Science and Research Department aided by the officers of the Bureau of Standards. At Bal-

timore there are a dozen or more men working on signalling and balloon problems under the general direction of Major Wood. At Pittsburgh, where the shops of the Carnegie Institute of Technology have been turned over to the work of the Physics and Engineering Divisions of the National Research Council, there are a dozen or more physicists, engineers, and mechanics working upon the design and construction of apparatus. At Columbia University there are some five or six men working on a special and important problem. Since the final testing is done under the authority of the Division of Military Aeronautics there are always a number of men who are at the aviation fields assisting in the making of final acceptance tests.

The work of the Science and Research Department outlined above covers the problems which come under the authority of the Bureau of Aircraft Production, the Division of Military Aeronautics, and the Signal Corps; but, through the activity of the Physics Committee of the National Research Council, investigations have been initiated which come within the authority of other Bureaus of the Army and the Navy.

Thus, the whole sound ranging work, the investigation of the location of aircraft by sound, and certain other allied investigations were transferred to the authority of the Engineers Corps after they had been gotten well under way by representatives of the Research Council. These representatives still act as an integral part of the groups, and the results of the investigations are reported by the Engineers Corps to the central office of the Research Council; so that the Division of Physical Sciences of the Research Council is still acting in an advisory and stimulating capacity in all these fields, and the problems themselves are discussed in the executive committee meetings of the Division of Physical Sciences.

The Anti-Submarine group, of New London, furnishes another illustration of the way in which these developments take place. The ten scientific men constituting this group were chosen in June, 1917, and their activities financed for a number of months by the Research Council, but the funds for their research work are now supplied entirely by the Navy. The reports of the results of this work are made, however, to the National Research Council, and the Executive Committee of the Division of Physical Sciences is represented in the New London meetings which are held each week.

Precisely similar relations are held in regard to certain problems coming under the authority of the Bureau of Ordnance of the Navy, the Ordnance Department of the Army, and the Coast Artillery Board.

The Executive Committee of the Division of Physical Sciences has met but twice during the past month. It has added a number of new problems to the list of approximately eighty which are receiving the attention of this Division.

Mr. E. F. Nichols, who is Chairman of the Committee on Submarine Mines of the Physics Division, has been employed by the Bureau of Ordnance of the Navy for the fuller development and production of devices relating to Naval Ordnance.

Division of Chemistry and Chemical Technology.—In addition to the regular meetings on Wednesday and Friday mornings the Division held a special evening meeting on August 28 for the purpose of discussing the arrangement of courses and recommending curricula for the war training of chemists and chemical engineers; this conference was attended by practically all of those now resident in Washington who are especially interested in chemical education. This matter had been referred to a special committee, the active members of which were H. P. Talbot and E. W. Washburn, who as a result of a questionnaire, had drawn up sample curricula designed to fit the special conditions now obtaining. It was found that the additional chemists required in the near future for government work will exceed 2000, with the probability that the needs for industrial work will be equally large. Analysis of the government requirements shows that about one-third of the number will need only training sufficient to enable them to carry out routine analytical and control work; the remainder will require a good general training with some degree of special training in one of the following: (a) physical chemistry, including electrochemistry and metallography; (b) organic chemistry, explosives in particular; (c) food and sanitary chemistry; (d) physiological chemistry; (e) chemical engineering. In accordance with the requirements two curricula, one for chemistry and one for chemical engineering, were proposed, for the purpose of training men needed as rapidly as possible; and after detailed consideration and discussion, two such sample curricula were recommended to the special committee of the War Department in charge of the whole matter.

The work of discovering chemical problems arising out of the war and assigning them to men at the universities and colleges is growing rapidly. To date thirty-four problems have been formulated, most of which have already been assigned, with the understanding that the research work will be prosecuted actively and that frequent reports of progress will be submitted to the Division. The list of subjects cover a wide range, from questions connected with chemical warfare to questions of conservation of materials a shortage of which is imminent.

Division of Geology and Geography.—In the absence of Messrs. Merriam and Cross, Mr. Gregory has acted as Chairman of the Division and also of the Section on Relations with Educational Institutions and State Committees. The chief work of the Division during August has been as follows:

1. Conferences with the Committee on Education and Special Training of the War Department with regard to plans for instruction in geology and geography for Army Training Units.

2. Conferences with geographers located in and near Washington with regard to geological instruction in universities and Army Camps during the period of the war.

3. Preparation of text books on Military Geology and Topography, Introductory Meteorology, and a syllabus on the Geography of Europe. Intro-

ductory Meteorology, a book of about one hundred and fifty pages, has been written largely by officers of the United States Weather Bureau. In the preparation of Military Geology and Topography the Acting Chairman has had the assistance of geologists and geographers in Government Bureaus and in universities.

4. Suggestions for training in map making and map interpretation in Army Camps, prepared largely by Mr. C. P. Berkey of Columbia University, have been submitted for discussion.

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD

AT THE NATIONAL RESEARCH COUNCIL BUILDING OCTOBER 8, 1918, AT 9.45 A.M.

Present: Messrs. Bogert, Cross, Dunn, Howe, Merriam, Millikan, Rous, Washburn, and Woodward.

The minutes of the preceding meeting, and of the intervening meetings of the Interim Committee, having been circulated by mail, were approved.

Mr. Dunn *moved:* That the following elections by the Interim Committee for membership in the National Research Council be recommended to the President of the National Academy of Sciences for appointment as members of the Council: Vice Chairmen, W. J. Lester (Engineering Division), E. W. Washburn (Division of Chemistry), Peyton Rous (Division of Medicine), and A. F. Woods (Division of Agriculture), together with C. E. Munroe, Chairman of the Committee on Explosives Investigations, and W. H. Howell, Acting Chairman of the Physiology Committee. (*Adopted.*)

Moved: That the whole matter of membership in the National Research Council be considered at a later meeting of the Board, at which time fuller information as to the appointment of members and recommendation for further appointment will be presented. (*Adopted.*)

Moved: That the election of the following as members of the Section on Industrial Research be confirmed: John Johnston, Chairman, L. H. Baekeland, G. K. Burgess, F. G. Cottrell, A. D. Flinn, C. E. K. Mees, Walter Rautenstrauch, W. R. Whitney. (*Adopted.*)

Moved: That the election of the following as members of the Advisory Committee of the Division of General Relations be confirmed: Theodore N. Vail, Chairman, Cleveland H. Dodge, George Eastman, E. H. Gary, A. W. Mellon, Pierre S. duPont, H. S. Pritchett, E. W. Rice, Jr., Elihu Root and Ambrose Swasey. (*Adopted.*)

Moved: That Peyton Rous be appointed Vice Chairman of the Division of Medicine and Related Sciences, in place of Major Yerkes resigned, and that he also be considered a member of the Executive Committee of said Division. (*Adopted.*)

Moved: That the pamphlet showing the present war organization of the Council be printed as of the present date. (*Adopted.*)

Moved: That the work of the National Research Council is of such importance to the Government that request might be made for deferred classification of men indispensable to its work; that office employees not engaged in research could not be considered as indispensable; and that cases of married men with families should be allowed to rest on the statement of the questionnaire, unless special circumstances make necessary a request for exemption. (*Adopted.*)

Moved: That the action of the Treasurer of the National Academy of Sciences in investing funds of the National Research Council, on deposit with the National Academy of Sciences, in readily negotiable bonds, be approved. (*Adopted.*)

The balance sheet as prepared by the Budget Committee was presented for consideration.

Mr. Dunn *moved:* That the Committee be congratulated on the work which has been done in preparing a statement of the accounts of the Council in such an understandable way and that a vote of thanks be transmitted to the Committee, to the Carnegie Institution of Washington and through that Institution to Mr. R. S. Woodward, Mr. John L. Wirt and Mr. E. A. Varela for the valuable aid which has been rendered in this matter. (*Adopted.*)

Moved: That all funds received either for general or special purposes of the National Research Council, with the exception of Government funds disbursed by the Council of National Defense, be handled in one bank account, and that all checks drawn against this bank account be signed by the Treasurer or Assistant Secretary and countersigned by the Secretary or Chief Clerk. (*Adopted.*)

Moved: That the Chairman be authorized to appoint a committee of three on Publicity and Publications, with the Secretary as an ex officio member, to consider the matter of preparation of accounts of the work of the Research Council for publication and to make recommendations. (*Adopted.*)

The Chairman appointed as members of the Committee on Publicity and Publications John Johnston, Vernon Kellogg and Walter M. Gilbert.

The meeting adjourned at 11.20 a.m.

PAUL BROCKETT, *Assistant Secretary.*

The following statements may be made relative to the work of Divisions of the Council during the past month:

Division of Engineering.—Progress continues in the studies undertaken by the Sections on Mechanical Engineering and Prime Movers, and a new subject of investigation concerning a special motor for aircraft, has been added to the list already under consideration.

In the Section on Metallurgy an additional committee has been appointed for a study of the improvement of metals by treatment at blue heat, under the chairmanship of Prof. Zay Jeffries, Director of Research of the Aluminum Castings Company.

In the Section on Electrical Engineering, important progress continues in the electric welding of ships. In particular the cause of the brittleness found at times in these welds has been discovered. About twelve different types of welded joints aggregating about one hundred samples, have been shipped to the Bureau of Standards for mechanical testing. A sub-committee on the metallurgical aspects of welding under the Chairman, S. W. Miller, has been formed. Investigations on the influence of the composition of the ship plates on the properties of the welded joint have been completed.

Division of Chemistry.—The work of procuring and assigning for investigation, war problems in chemistry and chemical technology is proceeding. Up to date forty-five such problems have been received and formulated. There is some uncertainty as to the effect which the inauguration of the Stu-

dent Army Training Corps at educational institutions is going to have upon this work. There seems to be some danger that in many cases the time of the chemists at the universities is going to be entirely taken up with instructional work, and that they will have no time to devote to research on war problems. It is hoped that in this case it will be possible to make use to an increasing extent of the research laboratories of industrial organizations with such laboratories. One of the war problems received from Chemical Warfare Service and assigned to the Research Laboratory of Physical Chemistry at the Massachusetts Institute of Technology has been progressing very satisfactorily and promises to be of very great value to the work of the Chemical Warfare Service. It may be stated that this problem has been attacked previously by other agencies but without success.

The Division is reorganizing its system of sub-committees on the following basis: Sub-committees which have been active and are doing important work in connection with the war will be retained and reorganized as special committees for certain lines of work. Other sub-committees will be discharged and replaced by a list of special consultants made up in most cases of the chairmen of former sub-committees.

At the request of the United States Fuel Administration, the Committee on Ceramic Chemistry has prepared a synopsis of a course in Chemistry of Combustion and Fuel Engineering for distribution to educational institutions. Up to the present time some thirty requests have been received for this synopsis. The synopsis was prepared by Mr. A. V. Bleininger of the Ceramics Committee and Prof. R. K. Hursch of the University of Illinois.

Division of Geology and Geography.—The work of the Division was under the direction of Mr. H. E. Gregory, Acting Chairman, for the first half of the month and under that of the Vice Chairman for the latter half. The duties of Acting Chairman of the Council having fallen on the Chairman of the Division, he requested the Vice Chairman to take charge of the work of the Division for the present. The principal work of the Division during September has been as follows:

1. The three textbooks for use in the S. A. T. C. courses in colleges and universities which have been prepared under the auspices of the Division (*Military Geology and Topography*, *Introductory Meteorology* and the syllabus on the *Geography of Europe*) have been completed and are now in course of publication by the Yale University Press. The completion of the manuscript and the reading of proof, etc., has taken a large amount of time.

2. Outlines of the courses in which these textbooks may be used have been presented to and approved by the Military Committee of the War Department on Education and Special Training. Many conferences have been held by the Chairman and Acting Chairman of the Division with the Military Committee in regard to the courses in geology, geography and topography.

3. Many conferences have been held and a large amount of correspondence

conducted with teachers of these subjects in the S. A. T. C. courses of various universities and colleges.

4. An examination of lantern slide material which may be available for the illustration of lectures in the S. A. T. C. courses on the Geography of Europe has been undertaken by Prof. E. B. Mathews of Johns Hopkins University as a committee of one for the Division, his necessary expenses to be paid from the appropriation for the Division.

5. Work of the Division in directions previously reported has been continued.

Division of Medicine and Related Sciences.—An important step taken by the Medical Division during the month was to send abroad Dr. Roger G. Perkins of Cleveland as Medical Associate of the Research Information Service in Paris. Dr. Perkins will inform himself of the medical research now going on in England and France and will submit reports from time to time with a view to correlating and stimulating research activities in this country.

Five hundred dollars was voted for study of the etiology of the so-called Spanish Influenza under the direction of Dr. W. H. Park of New York City.

Working committees were appointed for the improvement of transfusion methods; for the treatment of chronic anaemia; and for research along anatomical lines. Many progress reports have been received and several new researches instituted.

PAUL BROCKETT, *Assistant Secretary.*

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